Deloro Mine Site Cleanup
Industrial Area Closure Plan
Final Report

Prepared for:

ONTARIO MINISTRY OF THE ENVIRONMENT

Prepared by:

CH2MHILL

Responsible Solutions for a Sustainable Future

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Executive Summary

Background

The Deloro Mine/Refinery Site, located in Eastern Ontario, began operation as a gold mine in the 1860s. Over the next 100 years, site activities also included the smelting and refining of a number of other elements including arsenic, silver, and cobalt. Activities associated with the mining, smelting and refining of metals ceased in the 1950s. These historical activities at the site have resulted in significant environmental impacts to the soil, groundwater, surface water and sediment quality both onsite and offsite.

Abandonment of the site by its owner(s) forced the Ontario Ministry of the Environment (MOE) to take control of the property in 1979 and to initiate control measures to limit the environmental impact from the site. Remedial initiatives by the MOE have resulted in reductions of arsenic loadings to the Moira River. Arsenic loading to the Moira River has been reduced by more than 80 percent from an annual average of 52.1 kg/day in 1979 to an annual average of less than 10 kg/day since 1983.

To provide further treatment, and to mitigate any unacceptable impacts on human health and the environment, CH2M HILL Canada Limited (CH2M HILL, formerly CH2M Gore & Storrie Limited [CG&S]) was retained by the MOE to develop and implement a comprehensive rehabilitation program focusing on four individual areas of concern at the Deloro Mine Site. These areas included the Mine Area, the Industrial Area, the Tailings Area, and the Young's Creek Area. Subsequently, a detailed evaluation of rehabilitation alternatives was conducted by CH2M HILL in 2002/2003 separately for each of these four areas, which resulted in a rehabilitation alternative being recommended for each area of the site. CH2M HILL then further developed the recommended rehabilitation alternative by completing a separate Closure Plan for each area of the site. This report serves as the Closure Plan for the Industrial Area of the site.

The Industrial Area is where the smelting and refining of the various ores were carried out. Many of the by-products of these processes still remain in the Industrial Area, and include the following special materials: calcium arsenate, calcium arsenite, slag, and gold mine tailings. Investigations (CG&S, June 1999) indicate that some of the slag and tailing materials are low-level radioactive. Ferric arsenate sludge from the ATP, composed mostly of ferric arsenate, is also located in a settling lagoon in the southeast portion of the Industrial Area. Other miscellaneous materials, such as building rubble, box inspection holes, and metal storage tanks are also scattered throughout the site.

Groundwater monitoring indicates that the groundwater in the Industrial Area contains elevated levels of arsenic and other metals (e.g. cobalt, copper, mercury, and lead), while surface water monitoring shows that arsenic continues to enter the Moira River from the site. In 1996, for instance, surface water monitoring illustrated that a total arsenic load of approximately 3.2 tonnes/year from the Deloro site entered the Moira River.

A water and load balance model previously developed for the mine site (CH2M HILL, March 2002a) indicated that loading from the west bank of the Moira River is the main area of arsenic loading from the Deloro site, contributing at least 98 percent of the total loading. The analysis estimated that groundwater from the west bank of the Moira River contributes approximately 75 percent of the total site loading for arsenic with 69 percent of it from the Industrial Area. The analysis also estimated that surface water runoff from the west bank of the Moira River contributes approximately 7 percent of the total site loading for arsenic, but may be as high as 37 percent depending on the actual level of arsenic in the runoff.

Deloro Mine Site Cleanup Objective

The overall objective of the Deloro Mine Site Cleanup is to successfully rehabilitate the mine site to mitigate, within reason, any unacceptable impacts on human health or the environment. The overall closure objective is intended to achieve a 90 percent reduction in arsenic discharge to the Moira River to meet Provincial Water Quality Objectives (PWQO) at the intersection of the Moira River and Highway 7 (CG&S, October 1998).

As part of this overall objective, several area-specific objectives have been developed. Achieving these objectives, in conjunction with the other area-specific objectives, will aid in the successful rehabilitation of the Deloro Mine Site.

Recommended Remediation Alternative

An evaluation of remediation alternatives was previously conducted for the Industrial Area and the recommended comprehensive remediation alternative for the Industrial Area was:

Consolidate and Cover Wastes – Groundwater and Surface Water Flow Diversion

In principle, this alternative has the potential to minimize contaminant migration to the environment, is amenable to the addition of contingency features, if required, and is the most economical of the six comprehensive alternatives evaluated in the Industrial Area Alternatives Report (and taking into account the change from a shallow groundwater interceptor ditch to a horizontal well described below). Following consideration of a shallow overburden groundwater interception trench in the Industrial Area Alternatives Report, additional groundwater flow modelling of a number of new potential groundwater diversion/control scenarios for the Industrial Area was undertaken. The modelling results indicated that the most effective approach for diverting groundwater from the waste consolidation area and dewatering of the overburden, would include the installation of a north-south horizontal well placed into the bedrock on the west perimeter of the Industrial Area. The proposed system would also include installation of a network of eight vertical pressure relief wells, extending to 30 m into the bedrock, that would be connected to, or be in close proximity of, the horizontal well. The proposed groundwater interceptor well network (GIWN) would be a passive operation and would include a collector pipe to convey water from the horizontal well, via gravity flow, southward to the Moira River.

It is also proposed that vertical shafts would be installed at four of the pressure relief wells. These shafts would be designed to provide access to the horizontal and vertical wells at these locations to facilitate direct piping connections and for access for future flow control and monitoring, if desired. At the remaining four locations of the pressure relief wells, the system would rely on hydraulic connections between the wells through fractures in the bedrock. The hydraulic connections would be enhanced by hydraulic fracturing of the four vertical bedrock wells, to increase the hydraulic conductivity of the bedrock at these locations.

Risk Assessment

In support of the recommended rehabilitation program and as part of the development of the final management plan, CH2M HILL completed a draft screening level ecological risk assessment (SLERA) and a draft human health risk assessment (HHRA) to assess the risks associated with the Deloro Mine Site and Young's Creek offsite area following rehabilitation. The results of various exposure scenarios and receptors have been used in the Industrial Area Closure Plan to modify and optimize the conceptual remediation designs first presented in the Industrial Area Alternatives Report, as well as to satisfy the site-wide closure objectives. The draft SSRA recommended that the recommended Industrial Area rehabilitation alternative be modified to include an expansion of coverage around the western perimeter of the Industrial Area and to increase the thickness of any capped areas to at least 1.5 m to prevent exposure to burrowing animals and the potential risk of transmigration of contaminants via tree roots. The only exception to the capping requirement is the cap thickness over slag in the Industrial Area, which is set at 0.65 m since the slag constituents are immobile and not bioavailable.

Closure Plan for Industrial Area

Closure Plans have been developed for each of the four areas of the site based on the site-wide closure objectives, the area-specific closure objectives and the recommended rehabilitation alternatives developed for each area. Even though the Crown (i.e. the Provincial Government) is exempt from the requirements of the *Mining Act*, the Closure Plans have been developed to satisfy in general the requirements of the document entitled *Rehabilitation of Mines, Guidelines for Proponents* (MNDM, 1995). The latter document includes provisions for protection of the environment.

The Closure Plans will be the subject of additional public consultation and stakeholder review in addition to providing supporting documentation for regulatory reviews and applications. **It is anticipated that the Closure Plans may need to be revised, as a result of the public consultation and stakeholder review and to incorporate the findings of ongoing studies such as the Site-Specific Risk Assessment (SSRA) and groundwater modelling studies. Revisions are expected to refine the recommended alternative for each main area of the site but not result in a fundamental change in direction.** The comments and additional findings will be incorporated into the final rehabilitation strategy and implemented in the construction phase of the project.

The recommended remediation alternative for the Industrial Area contains the following components that are further developed in the Industrial Area Closure Plan:

- Site Security and Safety
- Building Demolition
- Site Preparation
- Waste Consolidation (for wastes to be covered by an engineered cover)
- Engineered Cover Installation
- Simple Earth (Clay) Cap Installation (over remaining wastes)

- Groundwater Interceptor Well Network
- Ongoing Leachate Collection and Treatment
- Riverbank Reconstruction
- Grading
- Site Revegetation

Future Flow to Arsenic Treatment Plant

The existing onsite groundwater collection system is designed to capture arsenic impacted groundwater before it reaches the Moira River. It consists of an Arsenic Treatment Plant (ATP), an 80-m-long cut-off wall grouted into bedrock located at the western bank of the Moira River, a 9,084-m^3 equalization pond, and six pumping stations (PS#1 to PS#6).

The ATP will receive increased flows from the proposed Tailings Area leachate collection system and the Tuttle Shaft, due to the planned increase to year-round pumping from several months of pumping per year, and from the proposed onsite containment cell in the Young's Creek Area. However, the overall future steady-state flow to the ATP is anticipated to decrease as a result of the anticipated reduction in flow rates from the existing pumping stations, following capping and installation of the GIWN. The estimated future steady-state flow rate to the ATP, following the implementation of the remedial measures (in the Industrial Area and other areas of the site), is anticipated to be approximately 198 m^3/day, less than both the current average treatment rate (approximately 274 m^3/day) and the maximum ATP capacity of 687 m^3/day.

It is also anticipated that contaminant concentrations will decrease with time as contaminated groundwater is removed from beneath the waste area and assuming that new leachate is not generated through direct contact of uncontaminated groundwater with the wastes.

It is anticipated that the existing groundwater collection and treatment system will continue in operation following completion of the planned rehabilitation program. Therefore, the decommissioning of the existing collection and treatment system is not specifically addressed as part of this Closure Plan.

Additional Hydrogeological Field Investigations and Modelling

Additional hydrogeological field investigations and modelling of the groundwater flow from the GIWN will be required to better estimate the future flow rates to the ATP, and to verify the depth of the horizontal well and the depth, number, and spacing of the vertical pressure relief wells.

Due to the uncertainty in hydraulic properties along the proposed alignment of the horizontal well, field work involving drilling and installation of pumping and observation wells, and pumping tests, need to be undertaken.

The field studies should include measurements of the Tuttle Shaft's static water level, in relation to the ground surface, to determine if the GIWN can depressurize the area so there is no artesian flow.

Following completion of the field program and data analysis, further groundwater flow modelling will be required to confirm the effectiveness of the proposed groundwater diversion/control solution. Depending on the data obtained during the field program, this modelling should also include evaluation of an additional groundwater diversion/control scenario. This scenario should incorporate a horizontal well constructed entirely in the overburden, in conjunction with vertical pressure relief wells constructed in the bedrock, to determine if effective groundwater flow control can be achieved.

Conservative contaminant transport modelling should also be undertaken to confirm the present analysis that the potential for contaminated groundwater to enter the horizontal and vertical wells, from under the engineered cover, is low. Currently, it is predicted that groundwater coming from the shallow bedrock under the engineered cover to the horizontal well and vertical wells will be diluted by a factor of approximately 12.9:1, when the entire flow into the system is considered.

Operation and Maintenance

Operation and maintenance efforts under the recommended alternative will be associated primarily with the ongoing operation of the ATP and groundwater collection and treatment system currently maintained by OCWA, and the periodic maintenance of the poplar trees, simple earth (clay) caps, engineered cover, GIWN, surface water drainage ditches, riverbank and perimeter fence.

Monitoring Program

The physical and chemical stability, water quality, and biological features in the Industrial Area will be monitored in phases during two site rehabilitation time frames:

- Construction Phase
- Operation, Maintenance, and Monitoring (OMM) Phase

Monitoring may occur daily, weekly, monthly or at other specified intervals. It is anticipated that sampling frequency will be gradually reduced as monitoring programs confirm the effectiveness of the rehabilitation measures in reducing the flux of arsenic migrating to the Moira River.

Expected Post-Closure Conditions and Uses

The final intended use of the site will be specified as a component of the federal Environmental Assessment (EA).

The post-closure topography in the Industrial Area will be heavily dependent on:

- The amount of highly leachable waste identified and excavated from areas
- The final grade of the land, which must be suitable for stormwater runoff yet minimize stormwater erosion
- The thickness of the engineered cover or simple earth (clay) caps applied to the area
- The amount of waste consolidated around the equalization pond

It is anticipated that the implementation of the recommended rehabilitation alternative for the Industrial Area will result in a marked improvement to the Moira River water quality, and be supportive of the overall closure objective of achieving a 90 percent reduction in arsenic discharge to the Moira River to meet PWQOs at the intersection of the Moira River and Highway 7 (CG&S, October 1998).

The post-closure risks to ecological receptors from the draft SLERA are not conclusive given information that is currently available. Additional site information is being collected and further risk evaluation is underway.

Malfunctions, Accidents, and Mitigation Measures

During the implementation and operation of the rehabilitative measures at the site, there is a potential that malfunctions (e.g. in design, construction, or commissioning) or accidents (e.g. due to acts of nature) could occur. These malfunctions and accidents can adversely affect remediation activities, and OMM of the site, resulting in delays or costly mitigation measures. These events must be considered and mitigation measures must be developed to ensure environmental impacts are minimal and acceptable. The Closure Plan identifies mitigation measures for potential malfunctions and accidents that have a reasonable probability of occurring at the site during three time frames:

- Short-term: Preparation activities
- Mid-term: Remediation activities
- Long-term: OMM activities

Health Hazard Assessment

A document entitled *Deloro Mine Rehabilitation Project – General Health and Safety Plan (GHASP), Final Report* (CH2M HILL, January 2002) has been developed to identify the main hazards and to provide a basis for the health and safety protocols. The GHASP identifies the following health hazards associated with the Deloro Mine Site that could be encountered while undertaking site inspections, site investigations, and remedial cleanup:

- Arsenic and arsenic compounds, other metals and silica
- Radiological hazards
- Heat and cold stress
- Buried utilities
- General physical (safety) hazards
- Biological hazards
- Chemicals existing at or brought onto site

Environmental and Community Health Protection Plan

The Environmental and Community Health Protection Plan (ECHPP) identifies potential risks associated with the cleanup of the site and recommends appropriate mitigation measures. Potential receptors that could be affected by the cleanup of the Deloro Mine Site include workers involved in the site cleanup, residents in the Village of Deloro, and residents and cottagers along the Moira River downstream of the site.

Since the transport of contaminants is most easily controlled at the source, the remedial activities selected for the site have been chosen based on the ability to minimize and control the disturbance, spread and loss of contaminants from the work area. Additional actions can be taken to further limit the spread and loss of contaminants from the work area and potentially offsite. These include measures to control dust, noise, odours, surface water runoff, surface water run-on, and erosion, as well as the use of appropriate equipment and personnel decontamination procedures. Each of these measures will be undertaken prior to and during implementation of the remedial activities. Odour control is not discussed since it is not expected to be of concern during implementation of remedial activities at the Deloro site.

A site-specific emergency procedures plan will also be developed and all site contractors will be expected to be familiar with and implement the site-specific emergency procedures plan as required.

Work Packages

Work packages identified for the Industrial Area rehabilitation program are listed below.

IDENTIFICATION OF INDUSTRIAL AREA WORK PACKAGES

Package ID	Industrial Area Work Package Description
IA-WP#1	Site Preparation
IA-WP#2	Demolition of Buildings/Tanks and Resizing/Consolidation of Ruins
IA-WP#3	Riverbank Reconstruction
IA-WP#4	Consolidation of Wastes
IA-WP#5	Simple Earth (Clay) Cap Placement
IA-WP#6	Engineered Cover Placement
IA-WP#7	Groundwater Interceptor Well Network
IA-WP#8	Site Revegetation
IA-OMM#1	Operation, Maintenance, and Monitoring (OMM)

The rehabilitation program schedule spans a five-year period to complete the following main tasks in the time frames provided:

- Year 1 – Site Preparation and Demolition (Duration: 60 days)
- Year 2 – Riverbank Reconstruction (Duration: 47 days)
- Year 3 – North Industrial Area Rehabilitation (Duration: 102 days)
- Year 4 – South Industrial Area Rehabilitation (Duration: 125 days)
- Year 5 – Groundwater Interceptor Well Network and Revegetation (Duration: 100 days)

If required, the rehabilitation program could be condensed to three years, requiring several work crews working simultaneously.

Cost Opinion for Each Work Package

The estimated cost of each work package is provided below.

WORK PACKAGE COSTS

Work Package Identification #	Description	Estimated Cost* (2004 dollars)
Capital Cost Items		
IA-WP#1	Site Preparation	$818,237
IA-WP#2	Demolition	$481,478
IA-WP#3	Riverbank Reconstruction	$831,012
IA-WP#4	Consolidation of Wastes	$913,535
IA-WP#5	Simple Earth (Clay) Cap	$4,025,504
IA-WP#6	Engineered Cover	$3,459,446
IA-WP#7	Groundwater Interceptor Well Network	$2,785,212
IA-WP#8	Site Revegetation	$253,595
	Total Capital Costs	**$13,568,019**
Operation, Maintenance, and Monitoring Cost Items (Annual)		
IA-OMM#1		
1.1	Arsenic Treatment Plant Operations	$577,371
1.2	Sludge Disposal (assuming 550 tonnes/year)	$177,131
1.3	Site Maintenance and Monitoring	$146,408
1.4	Groundwater Interceptor Well Network OMM	$26,468
	Total Annual (Weighted) OMM Costs	**$927,377**
Net Present Value of OMM Costs (includes remote location fees and overhead)		**$12,123,471****
Net Present Value of Capital and OMM Costs		**$25,691,490**

*All costs have been developed using 2004 pricing and do not include an escalation factor.

**Net Present Value (NPV) of Annual OMM Costs using an effective interest rate of 5 percent, and a planning horizon of 20 years.

As shown above, the estimated capital cost of the Closure Plan is $13,568,019 with annual weighted OMM costs of $927,377. The costs provided do not include engineering consulting fees, except for the OMM budgets. The net present value of the capital and OMM costs is $25,691,490, assuming an effective interest rate of 5 percent and a planning horizon of 20 years.

The costs presented in the above table include overhead and remote location costs, GST, a 15 percent contingency for the capital costs, a 5 percent contingency for the OMM costs, and the cost of various construction bonds and insurance associated with the capital costs. The costs presented are expected to have accuracy on the order of +/-25 percent. With exception, GST was not applied to the cost for the ATP operations that will continue to be conducted by OCWA. All costs were developed using 2004 pricing and do not include an escalation factor.

The capital cost of the GIWN was based on the current understanding of groundwater flow in the bedrock at the site and the results of groundwater flow simulations. This cost will be refined following further hydrogeological field investigations and groundwater flow modelling planned to be completed in 2004.

Budgets are entirely dependent on the volume of material to be excavated and compacted, not the time required to complete the work.

Approval Requirements

The primary site-wide regulatory approvals that must be applied for and issued by the appropriate government agencies are summarized below.

As confirmation that the actual cleanup is completed according to the SSRA, a Record of Site Condition (RSC) will be prepared and filed to document the cleanup. The RSC is completed jointly by the proponent, MOE, as well as the consultant overseeing the cleanup. The SSRA is a Level 2 Risk Management involving the use of engineered controls (e.g. engineered covers, groundwater pumping/treatment systems). A Level 2 Risk Management requires Registration on Title for the property to document the conditions of the land in the public domain. Registration on Title will be accomplished through filing a Certificate of Prohibition.

Other site-wide regulatory approvals that must be applied for and issued will be sought from the following agencies:

- MOE certificates of approval for sewage, and waste disposal; permits to take water (PTTW), and Part V approval under the provincial *Environmental Protection Act*.
- Conservation Authority regulations: the *Fill, Construction, and Alteration to Waterways Regulation*.
- The Ministry of Natural Resources (MNR) is responsible for issuing Work Permits under several different Provincial Acts including the *Forest Fire Prevention Act*, *Lakes and Rivers Improvement Act*, and *Public Lands Act*.
- The Department of Fisheries and Oceans (DFO) is responsible for the *Navigable Waters Protection Act* and the *Fisheries Act*. The Canadian Coast Guard (CCG) may also be involved.
- EA and Canadian Nuclear Safety Commission (CNSC) licensing will be required to manage the low-level radioactive and non-radioactive wastes on the site.

Even though the Crown (i.e. the Provincial Government) is exempt from the requirements of the *Mining Act*, the Closure Plans have been developed to satisfy, in general, the requirements of the document entitled *Rehabilitation of Mines, Guidelines for Proponents* (MNDM, 1995). MNDM has agreed to review the Closure Plans relative to accepted standards for closure and rehabilitation of mines in Ontario, although a specific approval will not be issued.

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List of Acronyms

AAQC	Ambient Air Quality Criteria
AECB	Atomic Energy Control Board
ATP	Arsenic Treatment Plant
C of A	Certificate of Approval
CCG	Canadian Coast Guard
CEAA	Canadian Environmental Assessment Act
CNSC	Canadian Nuclear Safety Commission
COC	Chemical of Concern
DFO	Department of Fisheries and Oceans
EA	Environmental Assessment
EAA	Environmental Assessment Act
ECHPP	Environmental and Community Health Protection Plan
EIS	Environmental Impact Study
EPA	Environmental Protection Act
FA	Federal Authority
GCL	Geosynthetic Clay Liner
GHASP	General Health and Safety Plan
GIWN	Groundwater Interceptor Well Network
GST	Goods and Services Tax
GUCSO	Guideline for Use at Contaminated Sites in Ontario
HADD	Harmful Alteration, Disruption or Destruction
HDPE	High Density Polyethylene
HELP	Hydrologic Evaluation of Landfill Performance
HHRA	Human Health Risk Assessment
HLW	Highly Leachable Waste
HQ	Hazard Quotient
LLRW	Low-Level Radioactive Waste
masl	Metres Above Sea Level
mbgs	Metres Below Ground Surface
MLS	Marginally Leachable Soil
MNDM	Ministry of Northern Development and Mines
MNR	Ministry of Natural Resources
MOE	Ministry of the Environment
MOEE	Ministry of Environment and Energy
MOL	Ministry of Labour
MRCA	Moira River Conservation Authority
NPV	Net Present Value
NSCA	Nuclear Safety and Control Act
NWC	New Westerly Creek
NWPA	Navigable Waters Protection Act
OCWA	Ontario Clean Water Agency
OMM	Operation, Maintenance, and Monitoring
OWRA	Ontario Water Resources Act

PC of A	Provisional Certificate of Approval
PPE	Personal Protective Equipment
PS	Pumping Station
PSW	Provincially Significant Wetland
PTB	Primary Treatment Building
PTTW	Permit to Take Water
PVC	Polyvinyl Chloride
PWQO	Provincial Water Quality Objectives
QC	Quinte Conservation
RA	Responsible Authority
RSC	Record of Site Condition
SDB	Standards Development Branch
SEC	Simple Earth (Clay) Cap
SLERA	Screening Level Ecological Risk Assessment
SPMDD	Standard Proctor Maximum Dry Density
SSB	Shared Services Bureau
SSRA	Site-Specific Risk Assessment
TDR	Time Domain Reflectometry
TERP	Transportation and Emergency Response Plan
TOR	Typical Ontario Resident
TSP	Total Suspended Particulate
VEC	Valued Ecosystem Component
VSC	Valued Social Component
WCA	Waste Consolidation Area
WNSL	Waste Nuclear Substance Licence

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1. Introduction

1.1 Background

This section describes a brief history of the Deloro Mine Site and the associated environmental issues that arose from more than a century of mining related activities, the need to rehabilitate the site, and the purpose and the organization of this document.

1.1.1 Deloro Mine Site

The Deloro site is located in Eastern Ontario along the banks of the Moira River (Figure 1-1) east of the Village of Deloro (Figure 1-2). The former refinery/smelter site (Industrial Area) is approximately 25 ha in area and is located adjacent to the west bank of the Moira River. The Tailings Area is located east of the Industrial Area between the east side of the Moira River and the west side of Young's Creek. The entire property, which includes the Industrial Area, Tailings Area, Mine Area, and the onsite portion of Young's Creek, is approximately 202 ha in area (CH2M HILL, February 2002). Access to the mine site is via Deloro Road, which is accessed from Highway 7, approximately 4 km east of Marmora. The principal population centres in the area are the Village of Deloro (pop. 180), and the Villages of Marmora (pop. 1,700) and Madoc (pop. 1,400), located approximately 5 km southwest and 10 km east of the mine site, respectively.

The Deloro site began operation as a gold mine in the 1860s and evolved over the next century to mine and refine gold, as well as smelting and refining of a number of other elements including arsenic, silver and cobalt. It was the first plant in the world to produce cobalt commercially and was also a leading producer of stellite, a cobalt-chromium-tungsten alloy. Concentrates from uranium extraction were imported to the site and further processed to extract cobalt. Arsenic-based pesticides were produced from the by-products of smelting operations and continued as a main activity at the site until the market collapsed in the late 1950s.

A century of handling hazardous materials and chemicals has resulted in significant environmental degradation of the Deloro Mine Site. Large quantities of refining slag, mine tailings, calcium arsenate, and arsenical pesticides remained at the site. Fuels, chemicals, and raw materials, such as sulphuric acid, coke, lime, soda ash, caustic soda, liquid chlorine, salt, scrap iron, sodium chlorate, and fuel oil were handled at the site. Low-level radioactive slag and tailings were produced as a result of the re-refining of by-products from uranium refining.

The Ontario government stepped in to take control of the site in 1979 due to failure of the owner to control environmental releases. The Ministry of the Environment (MOE) has been in care and control of the site since that time. Several rehabilitation actions have been implemented at the site that have significantly reduced releases from the site. In 1979, the annual average loading of arsenic to the Moira River was 52.1 kg/day. Since the Arsenic Treatment Plant (ATP) located in the Industrial Area of the site was put into operation in 1983, the arsenic loading to the river has been reduced by more than 80 percent, to an annual average of less than 10 kg/day. However, further work is required to reduce releases

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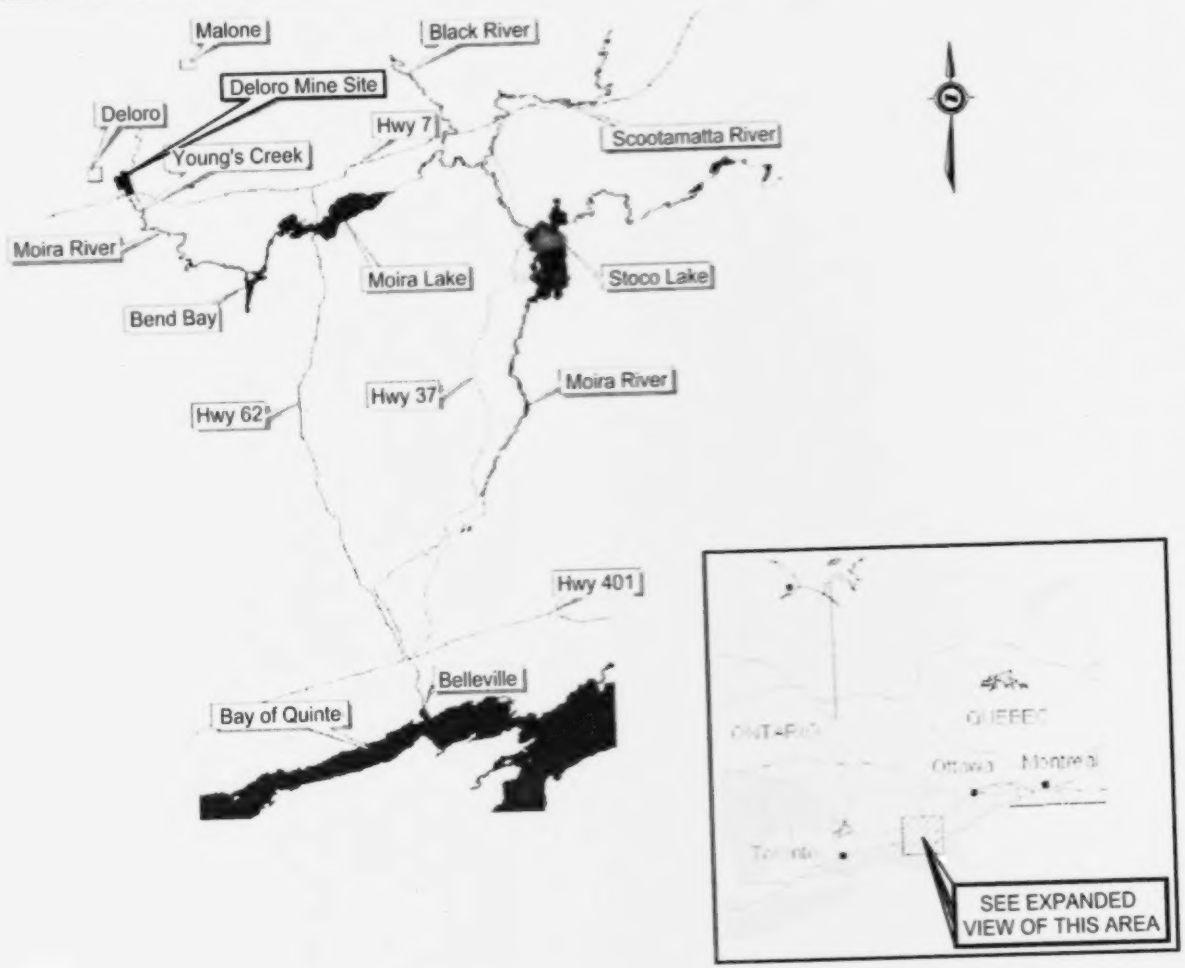
Malone
Black River
Deloro Mine Site
Deloro
Hwy 7
Young's Creek
Scootamatta River
Moira River
Moira Lake
Stoco Lake
Bend Bay
Moira River
Hwy 37
Hwy 62
Hwy 401
Belleville
Bay of Quinte
ONTARIO
QUEBEC
Ottawa
Montreal
Toronto
SEE EXPANDED VIEW OF THIS AREA

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PROJECT No 119548

DELORO MINE SITE CLEANUP

FIGURE 1-1
SITE LOCATION PLAN

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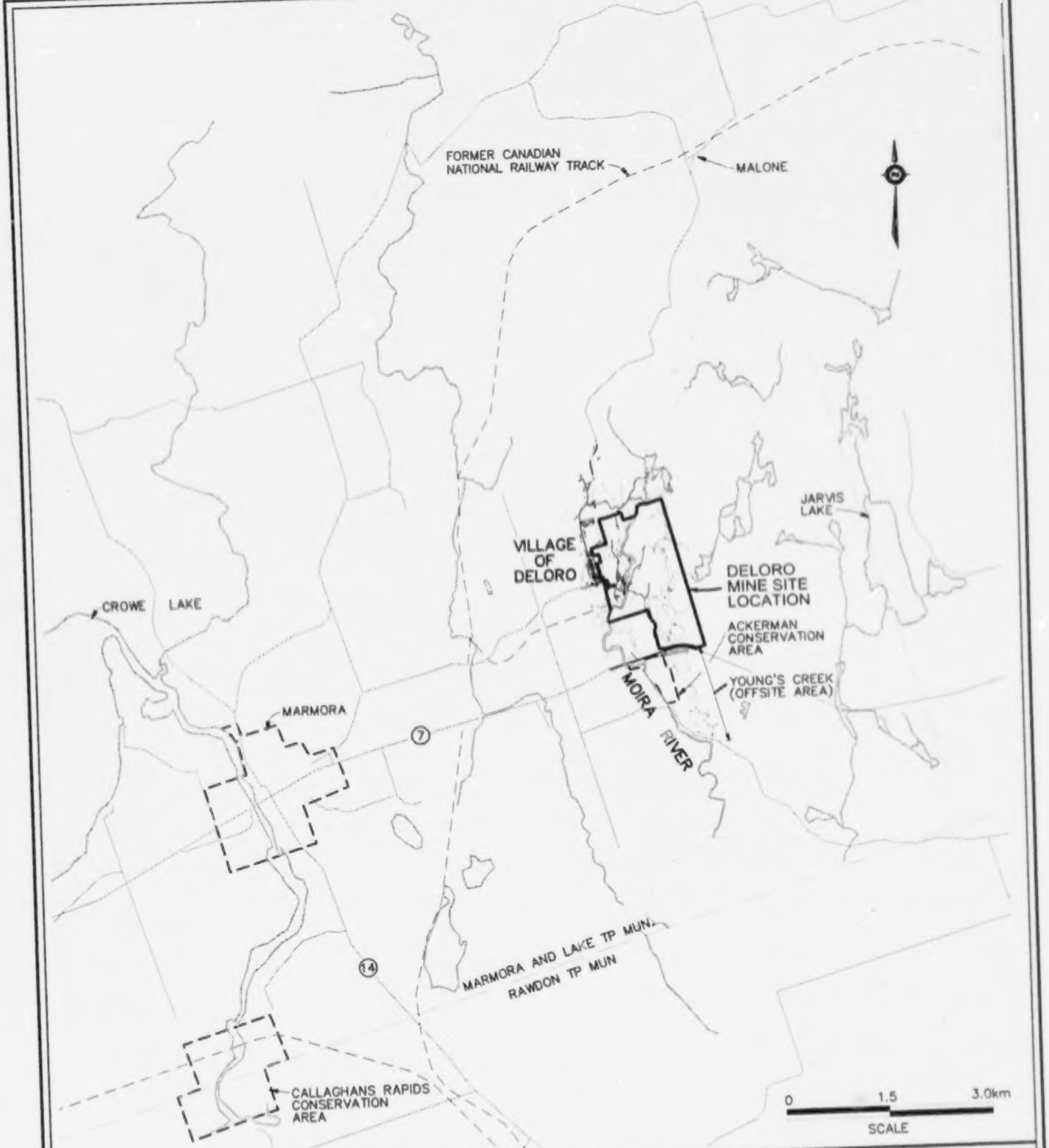
FORMER CANADIAN NATIONAL RAILWAY TRACK
MALONE
JARVIS LAKE
VILLAGE OF DELORO
DELORO MINE SITE LOCATION
CROWE LAKE
ACKERMAN CONSERVATION AREA
YOUNG'S CREEK (OFFSITE AREA)
MARMORA
7
MOIRA RIVER
MARMORA AND LAKE TP MUN
RAWDON TP MUN
14
CALLAGHANS RAPIDS CONSERVATION AREA
0
1.5
3.0km
SCALE

CH2MHILL

DELORO MINE SITE CLEANUP

FIGURE 1-2
DELORO MINE SITE LOCATION

PROJECT No. 119548

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to acceptable levels and to secure the site for the long term. CH2M HILL Canada Limited (CH2M HILL) was retained to provide consulting engineering and project management services for the Deloro Mine Site Cleanup.

1.1.2 Rehabilitation Alternatives

CH2M HILL was retained by the MOE to develop and implement a comprehensive rehabilitation program for the closure of this former mine site. As part of this comprehensive rehabilitation program, CH2M HILL evaluated a broad range of rehabilitation alternatives and identified a recommended alternative for further development for each of the four areas within the mine site's footprint, as shown in Figure 1-3. The limits of these four areas have been developed based on historical land use and waste disposal practices. The four areas are:

- The IA, where smelting and refining of the various ores were carried out
- The Tailings Area, where the by-products of the production phase were stored
- The Mine Areas, on both the east and west sides of the Moira River
- The Young's Creek Area, which has been impacted from historical releases from the Tailings Area

The rehabilitation alternatives reports prepared by CH2M HILL are as follows:

- *Deloro Mine Site Cleanup – Industrial Area Rehabilitation Alternatives* (December 2003a)
- *Deloro Mine Site Cleanup – Tailings Area Rehabilitation Alternatives* (October 2003a)
- *Deloro Mine Site Cleanup – Mine Area Rehabilitation Alternatives* (October 2003b)
- *Deloro Mine Site Cleanup – Young's Creek Area Rehabilitation Alternatives* (May 2003a)

1.1.3 Purpose of this Closure Plan

The overall objective of the Deloro Mine Site Cleanup is to successfully rehabilitate the mine site to mitigate, within reason, any unacceptable impacts on human health or the environment. As part of this overall objective, several area-specific objectives have been developed. Achieving these objectives, in conjunction with the other area-specific objectives, will aid in the successful rehabilitation of the Deloro Mine Site.

The Closure Plans for each of the four areas of the site are based on the site-wide closure objectives identified in the report entitled *Deloro Mine Rehabilitation Project – Development of Closure Criteria, Final Report* (CG&S, October 1998), including area-specific closure objectives (see Section 1.3), and the recommended rehabilitation alternatives developed for each area. The recommended alternatives are further developed in the four Closure Plans as follows:

- *Deloro Mine Site Cleanup – Industrial Area Draft Closure Plan*
- *Deloro Mine Site Cleanup – Tailings Area Draft Closure Plan*
- *Deloro Mine Site Cleanup – Mine Area Draft Closure Plan*
- *Deloro Mine Site Cleanup – Young's Creek Area Draft Closure Plan*

Even though the Crown (i.e. the Provincial Government) is exempt from the requirements of the *Mining Act,* the Closure Plans have been developed to satisfy in general the requirements of the document entitled *Rehabilitation of Mines, Guidelines for Proponents* (MNDM, 1995). The latter document includes provisions for protection of the environment.

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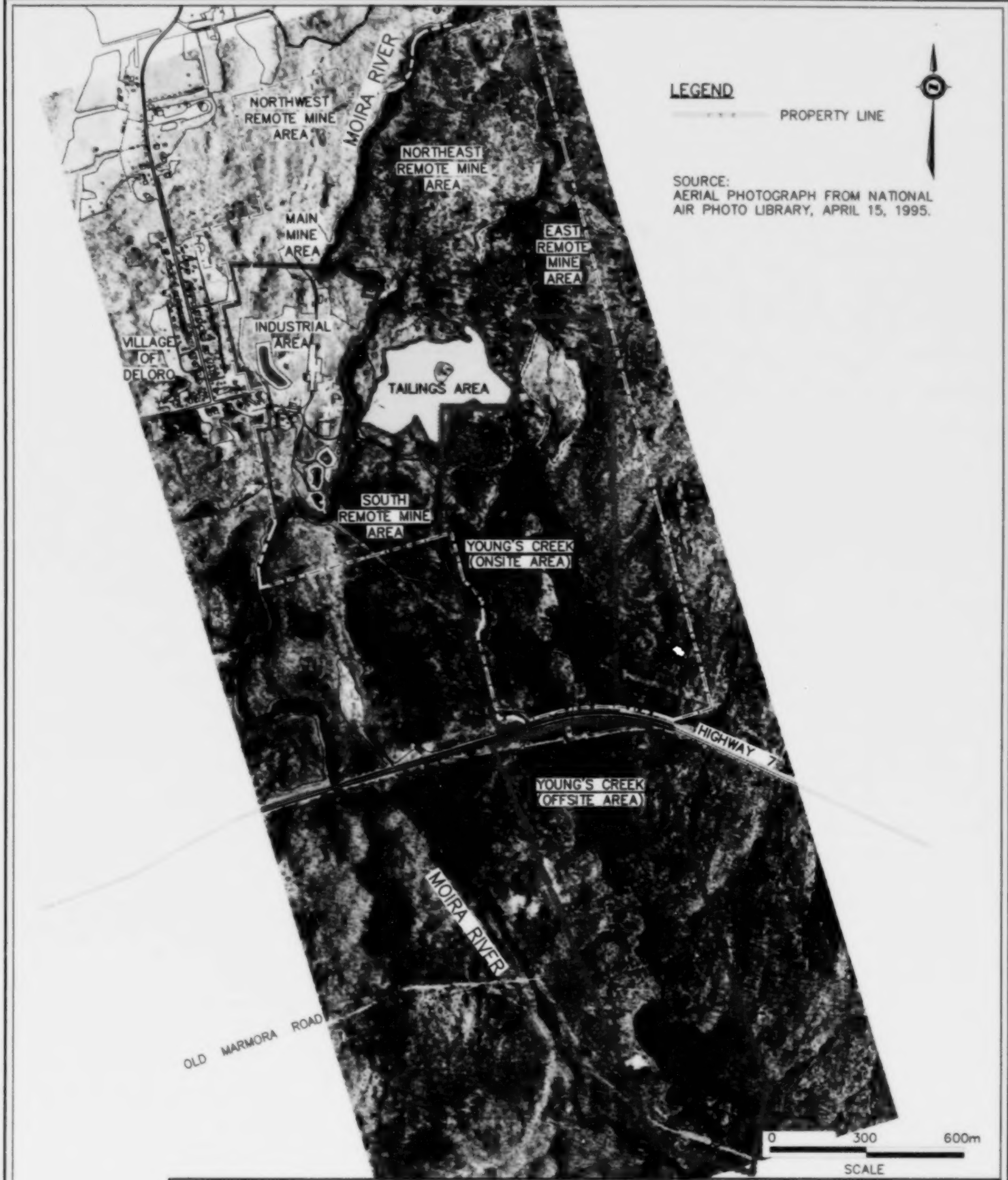
NORTHWEST REMOTE MINE AREA
MOIRA RIVER
NORTHEAST REMOTE MINE AREA
MAIN MINE AREA
EAST REMOTE MINE AREA
INDUSTRIAL AREA
VILLAGE OF DELORO
TAILINGS AREA
SOUTH REMOTE MINE AREA
YOUNG'S CREEK (ONSITE AREA)
HIGHWAY 7
YOUNG'S CREEK (OFFSITE AREA)
MOIRA RIVER
OLD MARMORA ROAD
0
300
600m
SCALE

LEGEND

PROPERTY LINE

SOURCE:
AERIAL PHOTOGRAPH FROM NATIONAL AIR PHOTO LIBRARY, APRIL 15, 1995.

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PROJECT No. 119548

DELORO MINE SITE CLEANUP

FIGURE 1-3: DELORO MINE/REFINERY SITE SHOWING THE INDUSTRIAL, MINE, TAILINGS AND YOUNG'S CREEK AREAS - DELORO, ONTARIO

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The Closure Plans will be the subject of additional public consultation and stakeholder review in addition to providing supporting documentation for regulatory reviews and applications. **It is anticipated that the Closure Plans may need to be revised, as a result of the public consultation and stakeholder review and to incorporate the findings of ongoing studies such as the Site-Specific Risk Assessment (SSRA) and groundwater modelling studies (see Section 2). Revisions are expected to refine the recommended alternative for each main area of the site but not result in a fundamental change in direction.** The comments and additional findings will be incorporated into the final rehabilitation strategy and implemented in the construction phase of the project.

An integrated technical cleanup plan will be prepared to present a summary of the four Closure Plans and to optimize and prioritize the remedial actions.

1.1.4 Organization of Report

This report consists of ten sections, including the introduction. Section 2 summarizes the findings of other technical studies undertaken to support the Closure Plans. A detailed description of the recommended alternative is presented in Section 3 including site security and safety, building demolition, waste removal and handling, waste isolation and containment, mine workings, crown pillars and surface workings, water management, final site grading, and site rehabilitation and revegetation. Section 4 presents an implementation plan for the selected alternative including identification, sequencing, scheduling and a cost estimate of work packages, anticipated construction impacts and mitigation measures, a health hazard assessment, an environmental and community health protection plan, and other operational procedures. Section 5 details operation and maintenance efforts outlined under the recommended remedial alternative. A recommended monitoring program is discussed in Section 6, focusing on physical monitoring, chemical stability and water quality, biomonitoring, and site management. Potential malfunctions and accidents and corresponding mitigation measures are examined in Section 7. Section 8 details the expected post-closure conditions and uses of the site. Known and anticipated approval requirements are outlined in Section 9, and Section 10 lists the references used in the preparation of this report. Details associated with the modelling of various groundwater diversion/control scenarios are contained in Appendix A and details associated with the opinion of cost information are contained in Appendix B.

1.2 Related Reports and Studies

A list of the reports and other documents referenced in this document is provided in Section 10. Related reports and studies are on public record and available for review from the Kingston MOE office.

The Ontario Ministry of Northern Development and Mines (MNDM) recommends that the Closure Plan include sections on "Current Environmental Conditions", a "Project Description", and a range of "Rehabilitation Alternatives". These three sections were provided in detail for the Industrial Area in the document *Deloro Mine Site Cleanup – Industrial Area Rehabilitation Alternatives, Final Report* (CH2M HILL, December 2003a) and therefore are not repeated in this report. The exception is the rehabilitation alternatives, which are listed in Section 1.4 below.

1.3 Cleanup Approach and Criteria

Extensive previous investigation and evaluation has been undertaken at the Deloro Mine Site. Based on strategic decisions made by the MOE in the early 1990s, the most viable solutions for management of residuals at the Deloro Mine Site involve onsite management through isolation and containment techniques. An approach that includes cleanup to "natural background" is prohibitively costly and is not considered to be the most prudent expenditure of public funds. Instead, a more pragmatic approach has been adopted in which mitigative action is directed at risk reduction. In this approach, risks to both human health and the environment are considered under both the current and reasonably expected future land uses. This approach has been recognized as an option in the MOE's *Guideline for Use at Contaminated Sites in Ontario* (GUCSO, [MOE, 1997]), in which it is referred to as the SSRA. The SSRA is the approach selected by the MOE as proponent for the Deloro site rehabilitation.

The strategic direction for site cleanup, involving the onsite management of wastes through isolation and containment methods as primary remediation techniques, is described in the report entitled *Deloro Mine Rehabilitation Project - Development of Closure Criteria, Final Report* (CG&S, October 1998). This translates into the following project objective:

> *To successfully rehabilitate the Deloro Mine Site to mitigate any unacceptable impacts on human health or the environment in compliance with relevant environmental policies and regulations.*

To satisfy this objective, specific site-wide and distinct area closure objectives were developed. The site-wide closure objectives are as follows:

1. Reducing the loading of arsenic and other contaminants to the Moira River
2. Compliance with appropriate regulations and policy
3. Satisfying the general intent of the *Mining Act* and related draft regulations
4. Reducing/controlling impact/risk to acceptable levels
5. Demolition of unneeded buildings to ground level
6. Prioritizing remedial action implementation according to risk reduction
7. Minimizing perpetual operation and maintenance
8. Restoration of the site to reflect its natural surroundings
9. Securing the site for the indefinite future
10. Managing the wastes over the smallest possible area

The overall closure objective is intended to achieve a 90 percent reduction in arsenic discharge to the Moira River to achieve Provincial Water Quality Objectives (PWQO) at the intersection of the Moira River and Highway 7 (CG&S, October 1998). Monitoring will be performed to assess actual performance. Contingency measures have been incorporated as part of the recommended alternative for each area of the site and are further developed as part of the Closure Plans. These site-wide closure objectives were further refined into area-specific closure objectives for each area of the site.

The following Industrial Area closure objectives reflect the overall remedial objectives for the Deloro site:

1. Develop a rehabilitation Closure Plan supported by a SSRA

2. Develop/implement risk reduction plans according to site-wide priorities

3. Remove wastes and residues from the area impacted by the design flood event
4. Provide flood protection for wastes/residues outside the design flood event
5. Manage low-level radioactive materials to reduce low-level radiation at ground surface to background levels
6. Cover and grade wastes/residues with material suitable to minimize infiltration
7. Isolate wastes/residues to eliminate, to the extent possible, releases to the environment according to the site-wide priorities
8. Co-manage wastes of similar risk (i.e. consolidate higher risk wastes and provide a suitably high degree of containment)
9. Design life for engineered facilities consistent with accepted design practice

1.4 Alternatives Considered

As previously noted, the Deloro Mine Site cleanup is being conducted according to the GUCSO (MOE, 1997) following the SSRA option. The approach has been adapted or enhanced to meet other regulatory or best management practices including the *Canadian Environmental Assessment Act* (CEAA).

A process was developed to generate potential remedial alternatives and select a recommended alternative for the Industrial Area of the Deloro site. This process is described in the Industrial Area Alternatives report (CH2M HILL, December 2003a). Initially, conceptual remediation methods that could have addressed some or all of the issues identified in the Industrial Area were identified, including:

- Do nothing
- Recycling/mineral recovery
- Enhanced groundwater collection
- Stabilization/solidification (including selected offsite disposal)
- Consolidate and cover
- Cap/cover in place
- Divert groundwater/surface water flow
- Full encapsulation
- Full encapsulation and contaminant leaching

These methods were evaluated with a screening process to identify which had the greatest potential to address the issues at the site, either alone or in combination with other methods. Improbable methods that did not have significant potential to contribute to a viable solution were eliminated early in the process. This resulted in the following list of primary remediation methods that were retained for further evaluation:

- Consolidate and cover
- Cap/cover in place
- Full encapsulation

The primary remediation methods were combined with the following enhancing environmental protection features:

- Enhanced groundwater collection
- Stabilization/solidification (including selected offsite disposal)
- Divert groundwater/surface water flow

Based on the judgment and experience of the project team, the primary methods and enhancing environmental protection features were combined to create the following 16 comprehensive remediation alternatives addressing all of the environmental issues at the site:

- Consolidate and cover
- Consolidate and cover - Ground/surface water flow diversion
- Consolidate and cover - Ground/surface water flow diversion, selected solidification
- Consolidate and cover - Ground/surface water flow diversion, selected offsite disposal
- Consolidate and cover - Ground/surface water flow diversion, enhanced groundwater collection
- Consolidate and cover - Ground/surface water flow diversion, selected solidification, enhanced groundwater collection
- Consolidate and cover - Ground/surface water flow diversion, selected offsite disposal, enhanced groundwater collection
- Cap/cover in place
- Cap/cover in place - Ground/surface water flow diversion
- Cap/cover in place - Ground/surface water flow diversion, selected solidification
- Cap/cover in place - Ground/surface water flow diversion, selected offsite disposal
- Cap/cover in place - Ground/surface water flow diversion, enhanced groundwater collection
- Cap/cover in place - Ground/surface water flow diversion, selected solidification, enhanced groundwater collection
- Cap/cover in place - Ground/surface water flow diversion, selected offsite disposal, enhanced groundwater collection
- Full encapsulation
- Full encapsulation - Enhanced groundwater collection

These comprehensive remediation alternatives were subsequently evaluated in a two-step process. The screening level evaluation again served to eliminate comprehensive remediation alternatives (as opposed to conceptual remediation methods that had been previously screened) that were unlikely to meet all of the remediation needs for the area. This second level of screening led to the following short list of six comprehensive remediation alternatives that were the subject of a more detailed evaluation:

- Consolidate and cover wastes - Groundwater/surface water flow diversion
- Consolidate and cover wastes - Groundwater/surface water flow diversion, selected offsite disposal

- Consolidate and cover wastes – Groundwater/surface water flow diversion, enhanced groundwater collection
- Consolidate and cover wastes – Groundwater/surface water flow diversion, selected offsite disposal, enhanced groundwater collection
- Cap/cover in place – Groundwater/surface water flow diversion, selected offsite disposal
- Cap/cover in place – Groundwater/surface water flow diversion, selected offsite disposal, enhanced groundwater collection

The detailed evaluation led to the identification of a recommended remediation alternative, which would be developed further and subsequently implemented to address the environmental issues at the site.

1.5 Overview of the Recommended Alternative

It was determined that the leaching of arsenic into the environment at the Deloro Mine Site appears to be effectively controlled in the short-term to the long-term by limiting availability of the wastes to the elements (i.e. wind, surface water, and groundwater). Therefore, the recommended alternative for meeting site closure objectives was based on:

- Ability to significantly reduce contaminant loading to the environment
- Minimizing the footprint of the leachable wastes in the Industrial Area
- Protecting these wastes from the elements by encapsulating them under an engineered cover designed to minimize infiltration or covering by a simple earth (clay) cap where less leachable wastes will remain (e.g. the slag and construction debris)
- Diverting groundwater from the wastes and surface water from the engineered cover
- Satisfying the design closure criteria for the site
- Compliance with regulatory requirements

The rehabilitation alternative recommended for the Industrial Area involves consolidating wastes under an engineered cover designed to minimize infiltration. Groundwater will be diverted away from the wastes and surface water away from the engineered cover by interceptor ditches located west of the Industrial Area and north of the consolidation area, respectively. A simple earth (clay) cap will cover portions of the Industrial Area where less soluble wastes will remain (e.g. the slag and construction debris).

1.6 Key Components and Recommended Alternative

The recommended comprehensive remediation alternative for the Industrial Area was:

Consolidate and Cover Wastes – Groundwater and Surface Water Flow Diversion

In principle, the recommended alternative has the potential to minimize contaminant migration to the environment, is amenable to the addition of contingency features, if required, and is the most economical of the six comprehensive alternatives evaluated.

However, the Groundwater Flow Simulation draft report (CH2M HILL, July 2003), discussed in Section 2.2.1,recommended that the groundwater flow diversion consist of a groundwater interceptor trench installed 2 m into the bedrock. During the development of this Industrial Area Closure Plan, it was determined that in some locations the installation could extend 7 m into the overburden and then require the blasting and clearing of 2 m of bedrock. For the duration of the excavating, blasting and trench installation the water table would have to be lowered more than 7 m.

Although the installation of a groundwater interceptor trench to divert groundwater flow is attractive from a low maintenance perspective, from a construction perspective, extending the trench 2 m into the bedrock is not a practicable solution.

The previously developed model for the Deloro Mine Site was used as the basis for modelling a number of new potential groundwater flow diversion/control scenarios for the Industrial Area. This additional groundwater flow modelling indicated that a groundwater interceptor well network (GIWN), comprising a north-south horizontal well placed into the bedrock on the west perimeter of the Industrial Area, was the most effective approach, of the alternatives evaluated, for diverting groundwater from the waste consolidation area (WCA). The horizontal well would be augmented with the installation of a network of vertical pressure relief wells that would extend to 30 m into the bedrock and would be connected to, or be in close proximity of, the horizontal well. Therefore, groundwater diversion for the recommended alternative would be achieved by the horizontal well and pressure relief wells rather than interceptor trenches.

The key components of the recommended alternative, and the sections in which they are discussed in further detail, are provided below:

1. Site security and safety (Section 3.1)
2. Building demolition (Section 3.2)
3. Site preparation (Section 3.4.1)
4. Waste consolidation (Section 3.4.1)
5. Engineered cover installation (Section 3.4.1)
6. Simple earth (clay) cap installation (Section 3.4.1)
7. Groundwater interceptor well network (Sections 2.2.2, 3.5.1, 3.5.2, and Appendix A).
8. Leachate collection and treatment (Sections 3.5.4 and 3.5.5)
9. Final site grading (Section 3.7)
10. Site revegetation (Section 3.8)
11. Riverbank reconstruction (Section 3.8.1)
12. Operation and maintenance requirements (Section 5)
13. Monitoring programs (Section 6)

2. Technical Studies and Supporting Documentation

The following section details technical studies and supporting documentation conducted to support the rehabilitation efforts at the site.

2.1 Human Health and Ecological Risk Assessment

The MOE has developed guidance documents specific to the SSRA approach, which have been followed for this project. CH2M HILL has conducted SSRAs for both the human health and ecological risks for all areas of the site, based on the remediation alternatives recommended for each area of the site and for various exposure scenarios and receptors. Results of these simulations have been used in the Closure Plans to modify and optimize the conceptual remediation designs first presented in the rehabilitation reports, as well as to satisfy the site-wide closure objectives. The SSRA also supports a Pathways Analysis, which is anticipated as part of the Canadian Nuclear Safety Commission (CNSC) licence application (see Section 2.3).

In support of the rehabilitation program and as part of the development of the final cleanup plan, CH2M HILL completed a draft screening level ecological risk assessment (SLERA) and a draft human health risk assessment (HHRA) to assess the risks associated with the Deloro Mine Site and Young's Creek offsite area following rehabilitation. The risk assessment was completed for the entire site, including the four main areas. This section presents a summary of the findings of the Deloro Mine Site SSRA and Young's Creek offsite area SSRA, respectively. Complete details concerning the HHRA and SLERA are provided in the following reports:

- *Deloro Mine Site Cleanup – Deloro Mine Site Site-Specific Risk Assessment, Draft Report* (CH2M HILL, May 2003b).
- *Deloro Mine Site Cleanup – Offsite Young's Creek Site-Specific Risk Assessment, Draft Report* (CH2M HILL, May 2003c).

2.1.1 Summary of SSRA Results

The results of the draft SSRAs performed at the Deloro Mine Site and in Offsite Young's Creek are summarized below for the expected post-closure conditions. Additional information is provided in the executive summaries of the respective draft reports.

Human Health Risk Assessments (HHRA)

- All chemicals of concern (COCs), with the exception of arsenic, show results below the MOE recommended target of 1×10^{-6} for carcinogenic risk. It is the opinion of CH2M HILL that comparison to the typical Ontario resident (TOR) is more appropriate for qualification of carcinogenic arsenic risk. The carcinogenic risks for arsenic were determined to be less than the risk to a TOR for all scenarios, receptors, and routes of exposure.

- Risk at levels greater than the MOE recommended target hazard quotient (HQ) of one for non-carcinogenic risk was identified for the onsite Child Recreational User due to exposure to soil (onsite), sediment (onsite and offsite) and surface water (offsite). These elevated post-closure risk results may be mitigated with expansion of the areas to be excavated and/or covered as part of the recommended rehabilitation alternative, or the results may be confirmed with additional sampling to confirm assumptions made in order to fill in the data gaps (see further discussion in Section 2.1.4 below).
- Young's Creek offsite post-closure Recreational User receptor risks were well below the comparison values previously identified. This may indicate that the rehabilitation effort originally proposed as part of the recommended rehabilitation alternatives reports can be reduced, assuming it also meets the requirements of acceptable risk to ecological receptors.
- Carcinogenic and non-carcinogenic risk due to ingestion of arsenic in onsite and offsite diet media (fish, ruffed grouse, berries) was greater than both the TOR and the HQ of one, respectively, for the Child and Adult Recreational Users. Confirmation of the presence and consumption of the diet media, as well as additional ecological data, is required to confirm these results.

Screening Level Ecological Risk Assessments (SLERA)

- Arsenic and cobalt are the COCs that are the main drivers of the elevated risk to onsite ecological receptors, as well as both pre- and post-closure Young's Creek offsite ecological receptors. Additional metals such as nickel, copper, chromium, and boron have also been identified as contributing to elevated risk to ecological receptors onsite and offsite.
- The results show that it is the concentration of the aforementioned COCs in soil that is of primary concern; however, elevated risk results have also been determined due to exposure to COCs in sediment and surface water.
- Almost all of the ecological receptors modelled show elevated risk at the screening level due to one or more COCs for one or more routes of exposure.
- A significant degree of uncertainty is associated with the draft results at the screening level due to lack of site-specific information and assumptions made in order to fill in data gaps.

2.1.2 Key Points

The following items should be considered in determining a path forward for the SSRA:

- The draft risk results for some pathways and receptors (both ecological and human) were not calculated using site-specific data; instead, engineering assumptions and literature-derived information were used.
- The risks to ecological receptors are not conclusive given the information that is currently available.

- The results of the draft human health risk assessment indicate that further risk reduction efforts are required should the future land use allow recreational users on the onsite property.
- Risk to both ecological and human health receptors may be mitigated by extending cleanup to a larger area, or by addressing the aforementioned data gaps by undertaking a focused field program.

2.1.3 Primary Issues of Concern

Based on the information presented above, there are two issues of primary concern. These arise because previous sampling work has focused on delineation of impacted areas for cleanup with relatively little focus on the post-closure conditions. The two primary issues are: (i) the absence of analytical data for certain chemicals in specific media, and (ii) the lack of site-specific information required to evaluate the potential risk due to exposure to the chemicals present.

2.1.4 Revisions to Recommended Rehabilitation Alternatives

The modifications to the recommended rehabilitation alternatives, which were identified through completing the draft SSRAs, included:

- Expansion of coverage around the western perimeter of the Industrial Area
- Total coverage of the Main Mine Area
- Excavation and/or capping of selected areas west of the Tailings Area to the Moira River
- Excavation of sediment from the Young's Creek Offsite area just south of Highway 7
- Excavation of sediment from the Young's Creek Offsite area just north of the confluence with the Moira River

In addition, in order to prevent exposure to burrowing animals as part of the SLERA (as well as due to the potential risk of transmigration of contaminants via tree roots), the thickness of any capped areas was increased to be at least 1.5 m[1]. These recommended modifications to the recommended rehabilitation alternatives are addressed in the Closure Plan for each area of the site.

2.1.5 SSRA Recommendations

The SSRAs provided to the MOE documented the presence of metal contaminant-related issues within the Deloro mine onsite area and Young's Creek offsite area under the post-closure condition for the recommended rehabilitation alternative. While the SSRA results did not show unacceptable risk under most conditions, it also indicated that there were potential risks to plants and animals residing within these areas, as well as to humans spending time on the respective properties, in some circumstances. The extensive characterization work at the site has focused on the areas requiring remediation, with less effort directed to areas that will remain post-closure. As a result, the data used to define the nature and extent of post-closure contamination and subsequent risk, or to establish acceptable risk-based cleanup levels, is being augmented through further investigative work. Further, the conclusions for potential risks to ecological receptors/valued ecosystem components (VECs) were primarily based on published reference values consistent with a screening level risk assessment (e.g. GUCSO). These values are not specific to this site, the activities that have taken place, or the types of contaminants present. In order to confirm that the recommended alternatives are appropriate and that remediation is not required over a broader area of the site (beyond the areas identified in the Closure Plans), additional site information is being collected and further risk evaluation is underway.

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[1] With exception, the cap thickness over slag and waste rock in the Industrial Area and Mine Area, respectively, was set at 0.65 m since these materials are not bioavailable.

The results of the supplementary site information and risk assessment will be used to fill in the data gaps, increase the confidence in the risk evaluation, and update the draft results of the HHRA and SLERA for both the Deloro Mine Site SSRA report and Young's Creek Offsite SSRA report. The revised reports will be prepared in a format that is suitable for submission to the Standards Development Branch (SDB) of the MOE for their review following the additional work. If necessary, the Closure Plans will be revised to address additional areas of the site that need to be capped or excavated.

The following briefly lists the studies that are ongoing to verify and substantiate the conclusions of the SLERA and the HHRA:

- Additional chemical characterization of onsite soil, sediment, and surface water
- Collection of biota co-located with soil, sediment, and surface water samples for evaluation of site-specific bioaccumulation
- Biological and physical surveys within the Young's Creek onsite area
- Toxicity testing of the Young's Creek onsite area
- Bioavailability of COCs in soil, sediment, and surface water

2.2 Modelling Studies and Predictive Assessments

The following section details modelling studies conducted to support the rehabilitation efforts at the site.

2.2.1 Groundwater Flow Simulations (2003)

Groundwater flow simulations were completed by CH2M HILL to support the development of cleanup plans for the Deloro Mine Site. The following findings, related discussion and recommendations of the Deloro Mine Site SSRA are drawn from the report, entitled *Deloro Mine Site Cleanup – Groundwater Flow Simulation, Draft Report* (CH2M HILL, July 2003).

The model concluded that bedrock provides considerable groundwater flow to the existing pumping station drains, having significant implications for any remediation scenario. Reducing recharge (infiltration) into the Industrial Area, where waste will be consolidated with an engineered cover, will reduce the infiltration through the waste and therefore reduce the volume of contaminated groundwater.

The 2003 modelling report concluded that the best potential to produce significant loading reductions to the Moira River from the Industrial Area was Scenario 4, the installation of a groundwater interceptor trench 2 m below the bedrock surface to the north, west, and south of the engineered cover.

The continued operation of the ATP and associated pumping stations (PS) PS#1 to PS#5 would still be required in the short-term; however, it is anticipated that PS#3, PS#4, and PS#5 may not be required in the future. The modelling analyses indicated that if implemented, this scenario would achieve the following:

- An 87 percent reduction in infiltration of precipitation and related contaminant loading from wastes that are consolidated beneath the engineered composite cover (no geosynthetic clay liner [GCL]).
- Interception and diversion of 92 percent of uncontaminated groundwater, which presently flows beneath the site and potentially becomes contaminated.
- Dewatering of the overburden and waste deposits in virtually all areas of the Industrial Area with significant contamination, with the exception of the southern extremities, further reducing the potential for groundwater to become contaminated.
- Reductions in flows to the Moira River to 58 percent of current values, of which very little comes in contact with the wastes or contaminated overburden soils and which is expected to be of much improved groundwater quality.
- The migration rate of any incidental contaminated groundwater that results below the engineered composite cover will be dramatically reduced over current levels (i.e. 41 and 45 percent reduction in migration rates in overburden and bedrock, respectively).
- A 59 percent reduction in flows to the current groundwater collection system is forecast and will subsequently lead to much greater reductions in contaminant loading to the treatment plant as concentrations are reduced over time.
- Significant potential exists to transition the current groundwater collection system from a primary system to a secondary or back-up system with time as steady-state conditions are approached and the inventory of chemicals in groundwater is reduced.

The 2003 modelling report recommended moving the waste and engineered cover to the north of the east-west site access road, to the area where dewatering of the overburden was determined to be more effective, based on the results of the modelling. That is, the south end of the engineered cover, originally shown in the Industrial Area Alternatives report (CH2M HILL, December 2003a), should be truncated further north of PS#3 and the waste removed from the southern extremities of the area that are not fully dewatered. This recommendation has been addressed in Section 3.4.1 of the subject Closure Plan (see Figure 3-6).

The 2003 modelling report also recommended that, due to the sensitivity of the groundwater flow predictions to the bedrock and local hydraulic conductivity, hydrogeologic parameters should be confirmed prior to final design to validate the model parameters and to provide the necessary design information.

2.2.2 Additional Groundwater Flow Simulations for Groundwater Interception (2004)

Evaluations undertaken subsequent to the completion of the 2003 modelling report indicated that constructing a groundwater interceptor trench 2 m below the bedrock surface would provide significant construction challenges. This is due to fluctuations in the elevation of the bedrock surface, the variable thickness of overburden above the bedrock (extending to a depth of 7m), and the need to blast and clear 2 m of bedrock. For the duration of the excavating, blasting, and trench installation the water table would have to be lowered more than 7 m. In addition, the available area is limited and may be insufficient to maintain stable side slopes of the drain in overburden during construction.

A passive groundwater diversion scenario is preferred because it supports the site-wide closure objective of minimizing perpetual operation and maintenance (Section 1.3). While a groundwater interception trench is largely a passive solution, the subsequent evaluation also indicated that the outfall of the interceptor trench would be below the bottom of the Moira River, which would require ongoing pumping of the intercepted groundwater to the river.

The previously developed model for the Deloro Mine Site was used by CH2M HILL in 2004 as the basis for modelling a number of new potential groundwater diversion/control scenarios, as part of the remediation of the Industrial Area. Scenarios evaluated with the model included the use of interceptor trenches, grout curtains/impermeable walls, horizontal wells, vertical pressure relief wells, and combinations of the above. As previously noted, specific details on the additional modelling of the various groundwater diversion/control scenarios evaluated are provided in Appendix A.

The overall objective of the groundwater diversion/control system would be to reduce the amount of uncontaminated groundwater that comes into contact with the wastes and as a result, the potential for contaminated groundwater to be transported eastward to the Moira River. To accomplish this primary objective, the system would be designed to accomplish the following:

1) Lower groundwater levels to an elevation that is below the wastes by depressurizing the bedrock and reducing the upward vertical hydraulic gradients from the deeper bedrock that currently exist beneath the Industrial Area.
2) Intercept non-contaminated groundwater that is flowing primarily eastward through the western site boundary before it flows through the area containing the buried wastes and diverting it around the waste area to the south to the Moira River.

Based on the 2004 modelling results, using the 12 groundwater diversion/control scenarios described in detail in Appendix A, the following conclusions are presented:

1. A shallow perimeter drain (Scenario 1) has little effect on dewatering the overburden.
2. A full or partial grout curtain, by themselves, will not be effective in dewatering the overburden (Scenarios 2 and 3).
3. A full or partial grout curtain combined with the shallow perimeter drain (Scenario 4) is not effective in dewatering the overburden.
4. A deeper grout curtain to 6 m below the bedrock surface combined with the shallow interceptor drain (Scenario 5) is not effective in dewatering the overburden.
5. Interceptor wells on the north and west sides of the proposed engineered cover (Scenario 6) appear to be able to effect dewatering of the overburden under the engineered cover. The pumping rates of the wells for this scenario could be more than 700 m^3/day. Particle tracking indicates that most of the groundwater pumped by the

wells originates from the north and west of the site, indicating that the water will likely be relatively uncontaminated.

6. Combining a partial grout curtain to 2 m below the bedrock surface with the interceptor wells (Scenario 7) would achieve dewatering of the overburden with marginally less water pumped from the wells. In both Scenarios 6 and 7, the line of zero saturated thickness adjacent to the west bank of the Moira River is under the eastern edge of the proposed engineered cover. This indicates that the eastern extent of the cover and any leachable waste in contact with the groundwater may have to be moved westward. This is true for the remaining scenarios.

7. A horizontal well of 0.5 percent slope placed in the bedrock just outside the north and west sides of the proposed engineered cover (Scenario 8) would achieve dewatering of the overburden if the elevation of the well is less than 184.21 metres above sea level (masl). Since the horizontal well outlet would be at an elevation of 182.8 masl it would need to be pumped to the Moira River. If the horizontal well is level, the well would have to be at an elevation of 184.0 masl to achieve dewatering of the overburden. Pumping would still be needed at the outlet.

8. A north-south trending horizontal well in the bedrock that extends north to the area of the Tuttle Shaft (Scenario 9) would work just as well as Scenario 8. The elevation of the well at its north end is 186.1 masl and 182.3 masl at the southern extension. Adding a partial grout curtain to the horizontal well (Scenario 10) achieves essentially the same dewatering result, but the flow in the horizontal well is 59 percent of the flow without the grout curtain. Whether the drain is horizontal or sloped, pumping would be needed at the outlet to convey water to the Moira River.

9. A north-south horizontal well in the bedrock, capable of discharging by gravity flow to the Moira River (Scenario 11), could achieve almost complete dewatering of the overburden. However, there is an area under the equalization pond that still has some saturated thickness, of up to 1 m in the overburden. There is also a strip of saturated overburden along the west side of the Moira River indicating that the eastern edge of the engineered cover and any leachable waste in contact with the groundwater may have to be moved west.

10. A north-south horizontal well in the bedrock, capable of discharging by gravity flow to the Moira River, combined with vertical pressure relief wells (Scenario 12) appears to be able to completely dewater the overburden. The overburden under the equalization pond, which was not completely dewatered in Scenario 11, is dewatered with the addition of the deep vertical relief wells. As in the previous scenario, a strip of saturated overburden on the west bank of the Moira River remains.

11. The modelling indicates that both Scenarios 11 and 12 have sound potential as preferred scenarios. Both are passive solutions requiring no pumping which could potentially dewater most, or all, of the overburden, if desired. In order to determine the feasibility of these options, and the number of vertical wells required, hydrogeologic field investigations and further modelling will be needed to determine the hydraulic characteristics of the deep and shallow bedrock in the area of the horizontal well and vertical relief wells.

12. The modelled groundwater levels in the municipal Deloro Well predict there will be relatively low interference associated with the groundwater interception of Scenarios 11 and 12. The difference in drawdown between the existing conditions pumping level and the Scenarios 11 and 12 pumping levels is up to 1.95 m in the Deloro Well. The available drawdown under existing conditions is 19.8 m. The available drawdown under these scenarios is between 17.9 m and 18.1 m for Scenarios 12 and 11, respectively. This indicates that there will still be adequate available drawdown to maintain the Village's water needs.
13. The pumping water elevation at the Tuttle Shaft is predicted to decline by up to approximately 0.9 m as a result of the groundwater interception of Scenario 12. This may be significant enough to reduce artesian flow from the Tuttle Shaft; however, more information is needed to determine the impact of this scenario on the Tuttle Shaft flow.

Based on the additional groundwater flow modelling of a number of new potential groundwater diversion/control scenarios for the Industrial Area, it was determined that the most effective approach for diverting groundwater from the WCA and dewatering of the overburden would include the installation of a north-south horizontal well placed into the bedrock on the west perimeter of the Industrial Area. In addition, a network of vertical pressure relief wells would also be installed, extending to 30 m into the bedrock and would be connected to, or be in close proximity of, the horizontal well (i.e. Scenario 12).

The proposed groundwater interceptor well network (GIWN) would be a passive operation and is discussed further in Section 3.5.2. In Appendix A, Figures 15 and 16 (Scenario 11) and Figures 18 and 19 (Scenario 12) show that the predicted hydraulic gradient along the horizontal well results in flow into the horizontal well screen and flow from north to south along the horizontal well alignment. Scenario 12 has been adopted in the Industrial Area Closure Plan, since it is a passive solution and is predicted to almost fully dewater the surficial deposits.

The 2004 modelling report (Appendix A) also states the following key recommendations:

1. The only solutions with passive elements that will dewater most, or all, of the surficial deposits under the engineered cover include a horizontal drilled well (Scenario 11) and a horizontal drilled well connected to vertical relief wells (Scenario 12) along the west side of the proposed engineered cover. Due to the uncertainty in hydraulic properties along the proposed alignment of the horizontal well, a hydrogeologic field investigation involving drilling and installation of pumping and observation wells, and pumping tests, needs to be carried out.
2. The field studies should include measurements of the Tuttle Shaft's static water level, in relation to the ground surface, to determine if the horizontal well can depressurize the area so that there is no artesian flow.
3. Following completion of the field program and data analysis, further groundwater flow modelling will be required to confirm the effectiveness of the proposed groundwater diversion/control solution. Depending on the data obtained during the field program, this modelling should also include evaluation of an additional groundwater diversion/control scenario. This scenario should incorporate a horizontal well constructed entirely in the overburden, in conjunction with vertical pressure relief wells

constructed in the bedrock, to determine if effective groundwater flow control can be achieved (see Section 3.4.1 for additional discussion).

4. Conservative contaminant transport modelling should be carried out to confirm the present analysis that the potential for contaminated groundwater to enter the horizontal and vertical wells, from under the engineered cover, is low. Currently, it is predicted that groundwater coming from the shallow bedrock under the engineered cover to the horizontal well and vertical wells will be diluted by a factor of approximately 12.9:1, when the entire flow into the system is considered.

2.3 Environmental Assessment

The MOE is seeking the necessary approvals to undertake a project involving the long-term onsite management of historic wastes, contaminated soils, and low-level radioactive wastes (LLRW) currently located at and in the vicinity of the Deloro Mine Site. The MOE understands that the licensing requirements for low-level radioactive materials management under the *Nuclear Safety and Control Act* (NSCA) require that an Environmental Assessment (EA) under the CEAA be completed.

A report was prepared entitled *Deloro Mine Site Cleanup – Project Description, Final Report* (CH2M HILL, November 2002) to provide the appropriate federal authorities with a project description and related information to initiate the federal EA process under the CEAA. The project description provided relevant project site information and an overview of the anticipated construction, operation, remedial work, long-term monitoring, and consultation activities that will be undertaken as part of the cleanup of the Deloro Mine Site, including the offsite portion of Young's Creek.

The CNSC, in co-operation with the federal Department of Fisheries and Oceans Canada (DFO), subsequently prepared a document entitled *Environmental Assessment Guidelines (Scope of Project and Assessment), Environmental Assessment of the Deloro Mine Site Cleanup, Deloro, Ontario* (CNSC, October 2003). The purpose of the latter document is to provide guidance on the scope of a screening level EA to be conducted for the possession, management, and storage of nuclear substances at the Deloro Mine Site.

The CNSC notes in its EA Guidelines that a federal EA is required under the provisions of the CEAA. Under the CEAA, the scope of the project and the scope of the factors included in the assessment are determined by the Responsible Authority (RA) for the project. The RA for this project is the CNSC. The DFO has indicated that it is a RA for this project if an authorization under the *Fisheries Act* is required; however, if it is not required, the DFO will withdraw as a RA but will remain as a Federal Authority (FA) for the project. The EA Guidelines describe the basis for the conduct of the EA and focus the assessment on relevant issues and concerns. This document also provides specific direction to the proponent, the MOE, for the conduct and documentation of the technical EA study report, the responsibility for which will be delegated to them by the CNSC and DFO pursuant to subsection 17(1) of the CEAA. The EA Guidelines also provide a means of communicating the EA process to stakeholders.

CH2M HILL is currently preparing the EA study report on behalf of the MOE and it will draw upon this and other Closure Plans.

2.4 Assessment of Likely Cumulative Effects

According to the CEAA, an EA must include an assessment of cumulative effects. CH2M HILL is addressing the assessment of cumulative effects in the EA study report. Cumulative effects will include an assessment of the potential effects of the Deloro Mine Site project in combination with the effects of other projects. In order to have a cumulative effect, the works and activities associated with other projects must overlap with both the geographical area and time frame of the Deloro Mine Site cleanup project. The cumulative effects assessment will be focused on the consideration of potential effects to valued ecosystem components (VECs) and valued social components (VSCs). If a cumulative effect is likely, then mitigation measures are applied and the potential effect is reassessed. If residual effects will be identified after the reassessment, then their significance will also be determined.

2.5 Other Studies and Evaluations

Two additional studies not discussed above, but currently in draft and under review by the MOE, were utilised in this report. These studies include:

- *Calcium Arsenate/Arsenite Waste Stockpile Mineralogy and Chemistry, Deloro Mine Cleanup Project, Draft Technical Memorandum* (CH2M HILL, December 2003b)
- *Results of the July 2003 Geotechnical Investigations for the Deloro Mine Cleanup Project, Draft Technical Memorandum* (CH2M HILL, December 2003c)

3. Description of the Recommended Alternative

The following section provides details of the recommended rehabilitation alternative's key components, which are listed in Section 1.6.

3.1 Site Security and Safety

At present, the Deloro Mine Site and the Ontario Clean Water Agency (OCWA) compound are completely enclosed by a 7,606 m perimeter fence that was installed in March 2000 (CH2M HILL, October 2003c). The majority of the chain link perimeter fence was installed to a height of 2.13 m, including 0.30 m of barbed wire. Adjacent to Highway 7, the perimeter fence was installed to a height of 2.13 to 2.44 m, without barbed wire to satisfy Ministry of Transportation's Permit requirements.

There are seven points of entry to the site, mainly along the southern and western property boundaries, including five 9.0-m wide gates (includes one 9.0-m wide gate installed in 2003), one 6.0-m wide gate, and one 1.2-m wide gate. Access gates will remain closed if not in use during the day and all gates will be closed and locked at the end of each working day to prevent public access to the site during remediation activities.

Access to the Industrial Area will be through the main site access gate near the ATP. The existing onsite access road will be used for construction vehicles to access these areas.

A group of three signs are affixed to the fence at distances varying between 50 m and 200 m, which read as follows:

- *Danger, No Trespassing, Positively No Admittance* (25 cm by 36 cm).
- *Caution, Radiation Area, Radioactive Materials, Authorized Personnel Only* (25 cm by 36 cm).
- *Mine Hazard Area, Danger: Every person who alters, impairs, or destroys this notice, this fence or any rehabilitation work made in accordance with Part VIII of the Mining Act, is guilty of an offence and, upon conviction, is liable to a fine of not more than $30,000* (30 cm by 30 cm).

During the construction phase of the project, signs would be used to caution the public along Highway 7, in the Village of Deloro, and at site entrances. Signage may include "*Trucks Turning*" and other construction warning signs as well as "*Danger – Access By Permit Only*" at access gates. Additionally, flagmen may be needed along Highway 7 to control traffic when heavy machinery or large transport trucks enter or exit the highway.

As mentioned above, access to the Industrial Area will be by the main access road into the site via Deloro Road. An assessment and reconstruction of the onsite bridge crossing the Moira River was recently completed as reported in CH2M HILL's report entitled *Deloro Mine Rehabilitation Project – Assessment and Reconstruction of Deloro Mine Site Bridge, Final Report* (CH2M HILL, June 2002). The key conclusions and recommendations of the report are:

- The existing site bridge in 1998 was not suitable for the future construction activities.
- Although the site bridge was reconstructed in 2000, there will be loading limitations during site rehabilitation. The following equipment should not be permitted to cross the reconstructed bridge:
  - A medium-tracked excavator
  - A loaded articulated truck
  - A loaded four-axle truck
- If future contractors plan to use other types of trucks with different axle spacing and loadings, then further analysis should be carried out by a design professional.
- The need for construction equipment to cross the Moira River during site rehabilitation should be assessed after completion of the various Closure Plans to prevent exceedances of the reconstructed bridge's loading capacity.

The safety of workers and the community and environmental protection are discussed in Section 4.6 (Health Hazard Assessment) and Section 4.7 (Environmental and Community Health Protection Plan), respectively.

3.2 Building Demolition

All above-ground structures at the Deloro Mine Site will be demolished to ground level as part of the Deloro Mine Site Cleanup, with the exception of the operating ATP, parking garage, and perhaps the powerhouse building, concrete trestle piers of the former primary treatment building (PTB) and portions of the castings building walls, which might be preserved as part of a heritage plan for the site.

Most of the former buildings have been demolished to some extent or are in various states of ruin, but the majority of the remaining buildings are currently unused and pose potential safety hazards.

Demolition materials that are uncontaminated could potentially be used for erosion protection as part of the reconstruction of the Moira River bank.

Contaminated demolition materials will be consolidated and managed along with the bulk of the impacted fill materials. To ensure that there is no low-level radioactive contamination of building materials, specified buildings (in which low-level radioactive materials were handled) will be surveyed for radioactivity prior to demolition. Those portions found to be radioactively contaminated will be moved into the area to be capped with an engineered cover. In addition to the buildings and infrastructure ruins, there is a large amount of rubble and waste spread in small piles about the Industrial Area, which will be collected to improve the general order of the site. All of the demolition materials will be size reduced wherever possible to improve the compaction qualities of the material. Some of the structures, such as the castings building, contain variable quantities of waste material, which will require proper handling and disposal.

Non-contaminated wood waste that is not suitable for onsite consolidation beneath the engineered cover will be reduced using a chipper or tub grinder. The resulting product will be used as a conditioner in the topsoil and simple earth (clay) cap, or consolidated and composted in a suitable area onsite.

The buildings that will require demolition, and the building ruins that will require resizing and consolidation, are listed below and identified in Figure 3-1. Structures with potential low-level radioactive contamination are identified with an asterisk.

A. Demolition of Buildings and Tanks:

- Castings building*
- Primary treatment building
- Powerhouse
- Three storage tanks

B. Resizing and Consolidation of Building Ruins:

- Cobalt oxide plant ruins*
- Cobalt packer house and plant dry building ruins
- Arsenic packing shed ruins
- Sludge lagoon ruins
- Boarding houses, hub, and kitchen ruins
- Lab building ruins
- Old treatment plant ruins

The following briefly describes the demolition work required at the above structures.

3.2.1 Castings Building

The largest of the remaining structures is the castings building, a 35 m by 43 m brick building resting on a sloping concrete foundation. Although the castings building has been identified by the MOE as one of the buildings for heritage potential, the majority of the structure is unusable and requires demolition. However, heritage usage may involve the restoration of portions of the walls.

The interior of the building is fabricated with open web steel joists to support the roof and wide flange steel columns to sustain the weight of the building envelope. All of the glass has been removed from the window openings. The roof is constructed of a timber deck over timber stringers and has partially collapsed in some areas.

The eastern addition (metals plant) of the castings building has already been demolished. Sections of the floor are located over a crawl space that may have to be filled with a controlled low strength material to ensure it does not compromise the integrity of the engineered cap or create any preferential pathway for groundwater flow. Where possible, the floor should be caved in to ensure that the best possible compaction is achieved during construction.

Much of the demolition debris from this building can potentially be recycled by controlling the mixing of the recoverable scrap metals with wood waste and brick rubble. Several loads of scrap metal can likely be recovered by sorting through the existing rubble.

There are several waste drums and bags of lime remaining within the building, which will be removed and disposed offsite or crushed, consolidated and managed onsite with wastes of similar character.

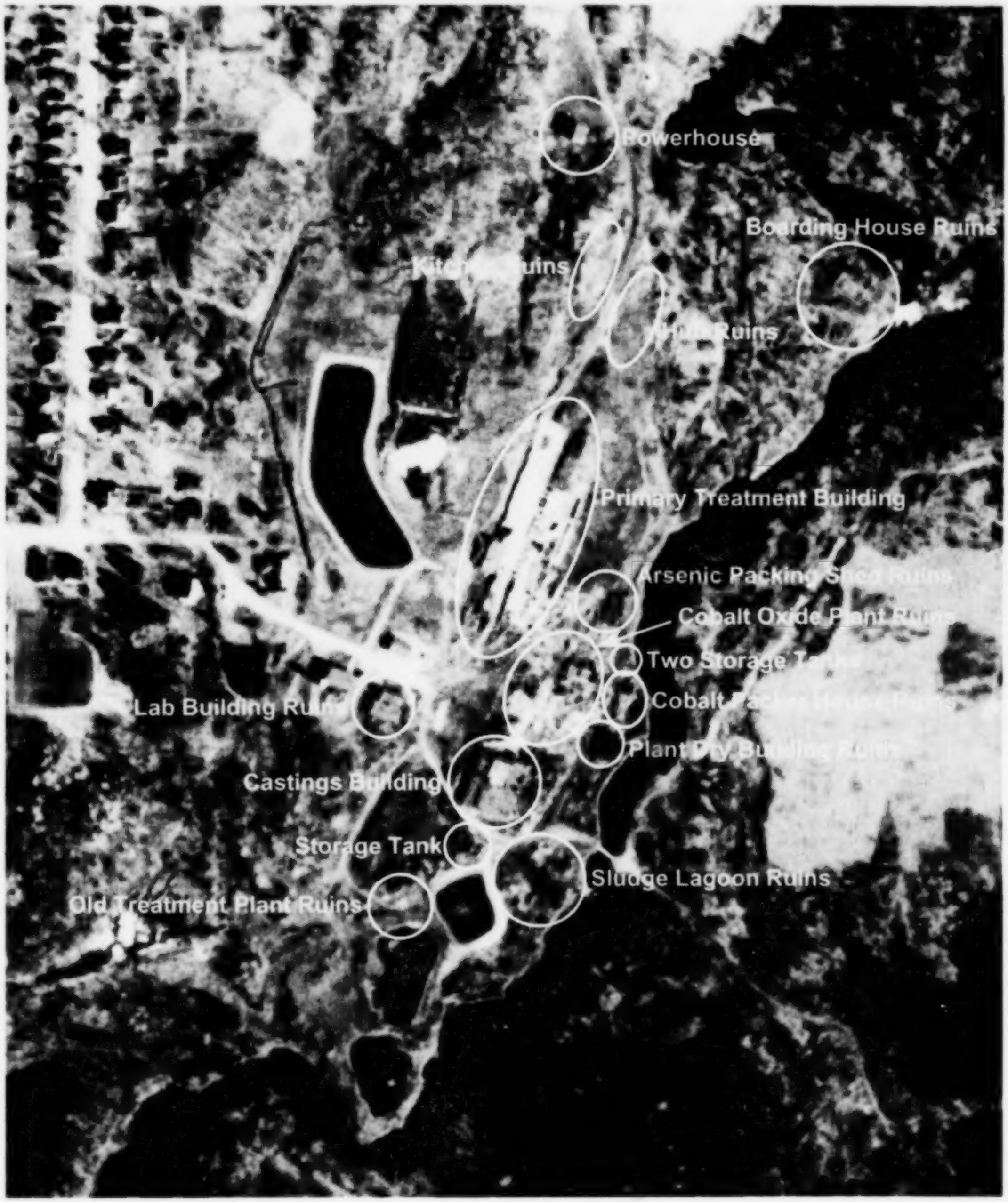
Powerhouse
Boarding House Ruins
Kitchen Ruins
Mill Ruins
Primary Treatment Building
Arsenic Packing Shed Ruins
Cobalt Oxide Plant Ruins
Two Storage Tanks
Lab Building Ruins
Cobalt Packer House Ruins
Plant Dry Building Ruins
Castings Building
Storage Tank
Sludge Lagoon Ruins
Old Treatment Plant Ruins

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Figure 3-1
Location of Structures to be Demolished

3.2.2 Primary Treatment Building

Several heavy demolition tasks will take place in this area. In order to ensure proper grade slopes, all structures above the 198 masl grade line, which is the elevation of the PTB floor slab, must be demolished.

The eleven concrete trestle piers on the former PTB slab have been identified by the MOE for heritage potential. The trestle piers are heavily reinforced concrete and span a total distance of 97 m. Should it be determined that the trestle piers will not be preserved, the demolition work should allow for the use of an excavator with a hydraulic breaker assembly without any significant preparatory work being performed.

The remains of the elevator shaft will be demolished to the ground. The shaft will be pumped and filled with grout to seal the void. The shaft is approximately 5 m deep and will need a retaining wall at the bottom to restrict the flow of grout to the shaft.

Small support walls and non-structural members are present at the north end of the deck. These will also be demolished to grade. A parapet lines the eastern and interior walls. This parapet will require removal in order to establish a level surface.

A suspended slab is present at the east end of the primary treatment area. The portion of the slab that is overhanging the lower wall is being held in place by corrugated plate and wide flange beams. The beams can be recycled and the fallen slab will be consolidated with the rest of the waste materials. The remainder of the slab has been set on a checker plate base supported by wide flange beams. It will be removed along with its corresponding metal members.

There is a receiving bay at the northeast end of this building area. The walls are approximately 0.5 m wide and heavily reinforced. These walls will be demolished until there is no threat of the void space compromising the engineered cap function.

3.2.3 Powerhouse

The powerhouse is a two-storey, free-standing building constructed of cut limestone blocks. The building measures 8.5 m by 11 m. The northwest corner of the building shows signs of minor differential settlement. The powerhouse is one of the buildings that has been identified by the MOE for heritage potential. Should it be determined that it will not be preserved, the limestone blocks will be crushed and used as fill onsite.

3.2.4 Three Storage Tanks

There are two metal storage tanks that formerly stored heavy and light fuel oil, which are recessed into concrete vaults. The tanks will be cleaned and removed. The surrounding concrete storage vaults will be demolished to grade or completely removed. A third metal tank that formerly stored oil is located immediately south of the castings building. This tank will be cut, crushed, or removed from the site. All three metal tanks have been drained of product, although some sludge may remain in the tanks.

3.2.5 Cobalt Oxide Plant Ruins

Several concrete structures remain from the cobalt oxide plant, which covered an area of approximately 62 m by 46 m. Thick diamond meshed reinforced concrete foundation members were left standing from the original demolition. These structures have many conduits and open void spaces. The void space will be eliminated to ensure proper compaction can be achieved. This will likely involve the combined effort of small explosive devices and an excavator with a hydraulic breaker to demolish the remains to ground level.

3.2.6 Cobalt Packer House and Plant Dry Building Ruins

Consolidation of the remaining brick rubble and wood waste is required at these two buildings.

3.2.7 Arsenic Packing Shed Ruins

The arsenic packing shed has already been demolished but a large amount of wood waste is still present in this area.

3.2.8 Sludge Lagoon Ruins

The remains of three foundations are located adjacent to the east side of the active ferric arsenate sludge lagoon. These foundations will be removed to ground level and consolidated.

3.2.9 Boarding Houses, Hub, and Kitchen Ruins

Concrete foundations remain from the former boarding houses near the Deloro falls. These foundations will be reduced to ground level.

Much of the area has been littered with empty barrels and piles of slag. The barrels will be crushed in order to reduce volume and then be recycled or consolidated. This unknown quantity of slag will be segregated and used as excavation backfill in the North and South Industrial Areas with other similar wastes (see "Slag" in Table 3.2).

A 36 m by 15 m concrete slab and lower wall of the Hub dining room still remain. The slab was poured over the bedrock outcrop adjacent to the road leading to the Tuttle Shaft. It may be possible to cap the remains of the Hub in place.

Some ruins of the kitchen, located immediately west of the Hub, may still exist, and will be reduced to ground level and capped in place.

3.2.10 Lab Building Ruins

The lab building has already been demolished. It was a 21 m by 20 m, two-storey, flat-roofed building constructed of concrete blocks, brick, and clay tiles. The wood waste will be separated from the other materials and size reduced in a tub grinder. The remaining waste will be consolidated. A concrete foundation remains and will be removed by use of an excavator with a hydraulic breaker. This location may require the foundation to be completely removed, as it is in close proximity to the main entrance and is founded on bedrock.

3.2.11 Old Treatment Plant Ruins

This one-storey wood structure held a ferric chloride tank for the original treatment of the arsenic bearing waters. The building is approximately 10 m by 20 m and will be demolished to ground level. Wood wastes will be reduced in a tub grinder and disposed of in a manner similar to that mentioned above.

3.3 Waste Removal and Handling

As shown in Figure 3-2, the Industrial Area has been subdivided into 26 areas, labelled A to Z, to aid in the development of a waste consolidation and cover strategy. Each area exhibits characteristics distinguishable from other areas. Areas were divided based on one or more of the following - waste type, topography, soil stratigraphy, existing site operations, engineered cover location, simple earth (clay) cap location, bedrock outcrop location, and, in the case of Area Z, the location of the 100-year flood boundary. The waste consolidation and cover strategy is discussed in greater detail in Section 3.4.

This section describes the main wastes and their general location (Area A to Z). The removal, handling, transportation and conditioning, if required, of these wastes during the implementation of the Industrial Area rehabilitation alternative are also discussed. Waste volumes are discussed in Section 3.4.1.

3.3.1 Main Waste Types

The main waste products generated during past operations at the Deloro site included:

- Building rubble
- Barren solutions
- Laboratory wastes
- Arsenic compounds
- Ferric arsenate sludge
- Ferric hydroxide tailings
- Gold mine tailings
- Low-level radioactive materials - tailings and slag (includes low-level radioactive slag and contaminated soil transferred from Village of Deloro)
- Non-radioactive slag
- Ackerman Conservation Area wastes
- Miscellaneous wastes

Descriptions, quantities and locations of the miscellaneous wastes are described in Section 3.3.2. All other wastes are described in Section 3.3.3 - Waste Inventory.

3.3.2 Miscellaneous Wastes

The small quantities of miscellaneous waste materials listed in Table 3.1 are widely distributed within the Industrial Area.

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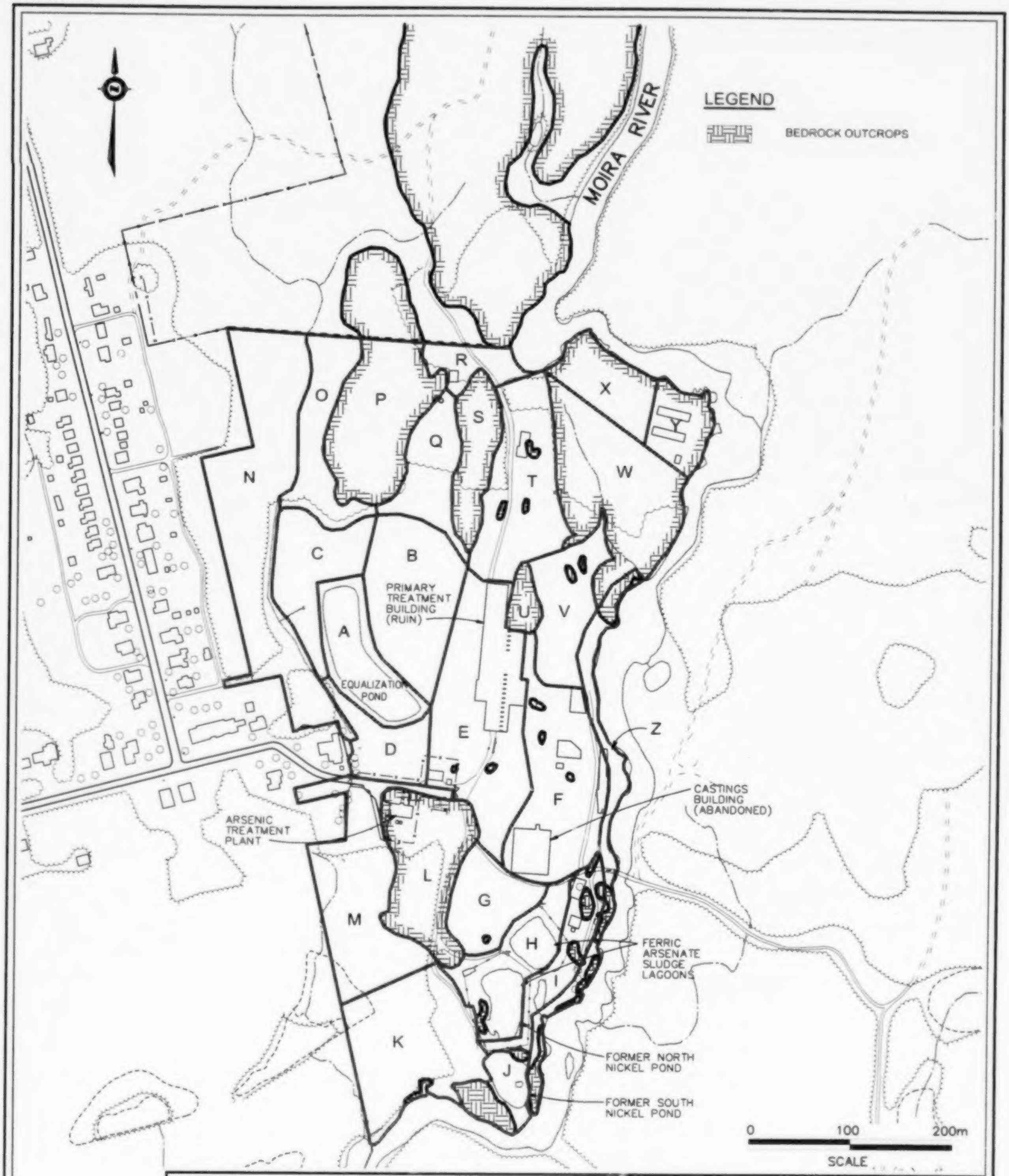
LEGEND
BEDROCK OUTCROPS
MOIRA RIVER
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y
Z
PRIMARY TREATMENT BUILDING (RUIN)
EQUALIZATION POND
ARSENIC TREATMENT PLANT
CASTINGS BUILDING (ABANDONED)
FERRIC ARSENATE SLUDGE LAGOONS
FORMER NORTH NICKEL POND
FORMER SOUTH NICKEL POND
0
100
200m
SCALE

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INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

FIGURE 3-2
SUBDIVISION OF THE INDUSTRIAL AREA

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TABLE 3.1
LOCATION OF MISCELLANEOUS WASTES

Area	Miscellaneous Waste Description
K	Miscellaneous wastes and impacted fill; dump containing building rubble, ash and silty clay, arsenic laced lime, a white powder, metal debris, wire, wood
L	Chemical dump containing wastes from a chemical lab, building rubble, old drums and empty sacks of hydrated lime; mostly bedrock outcrop with thin overburden
M	Chemical dump containing wastes from a chemical lab, building rubble, old drums and empty sacks of hydrated lime
T	Asbestos sheeting tile dump
X	Asbestos sheeting tile dump
Y	Dump with empty barrels, slag and asbestos tile sheeting
Z	Former location of two large oil tanks; scrap metal lines the west riverbank

There is approximately 400 m^3 of wood waste and approximately 850 m^3 of miscellaneous solid waste located throughout the Industrial Area. The wastes will be managed as follows:

- Wood waste will be resized and mulched, then spread over the final covers prior to vegetation, provided the wood is not impacted by preservatives or contaminants
- Due to the potential for decay and settlement, in-situ management of non-hazardous, contaminated wood, such as creosote-coated railway ties, is problematic and would therefore require offsite disposal at a landfill
- Select non-hazardous scrap steel/iron wastes might be recycled offsite, if feasible
- Empty drums and tanks will be crushed onsite and consolidated under the engineered cover area
- Contaminated water and liquid wastes in tanks or concrete vaults will be pumped out and disposed offsite at a licensed facility
- All hazardous miscellaneous wastes, asbestos sheets, bricks, etc. will be managed onsite.

3.3.3 Waste Inventory

The main site wastes listed are described below. Table 3.2 describes the wastes, and the location of the wastes is identified in Figure 3-2.

Building Rubble

Building demolition has created large rubble piles throughout the Industrial Area consisting mostly of wood, concrete, and brick. These were used as fill in several locations in Areas E and F, with lesser accumulation of rubble in Areas H, I, L, O, R, T, and Y. There is approximately 80 m^3 of concrete building rubble in the Industrial Area and an additional 100 m^3 of concrete in the buildings to be demolished. Figure 3-1 identifies the current location of building ruins and rubble.

Barren Solutions

Barren solutions were historically discharged to the north and south nickel ponds in Areas H and J for precipitation/settling of metals, prior to discharging the pond water to the river. The nickel settling ponds are no longer in use. The south pond is reportedly constructed on

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Table 3.2
Waste Inventory and Consolidation Program

Area I.D.	Estimated Surface Area (m^2)	Estimated Mean Depth of HLW (m)	Estimated Volumes (m^3)	Estimated Volume of HLW to Consolidate (m^3)	General Waste Description	Rationale for Consolidation	Consolidation Area
A	7,993	0.0	0	EP	Equalization pond (EP) constructed adjacent main CAA stockpile		
B	12,775	3.7	47,268	*	HLW; main CAA stockpile	*HLW (0 mbgs-bedrock)	*
C	8,171	1.0	8,171	*	HLW; gold mine tailings from the northwest arm of the Industrial Area; waste rock; red mud tailings (ferric hydroxides)	*HLW (0-0.3 mbgs)	*
D	5,109	3.0	15,327	*	HLW; red mud tailings (ferric hydroxides)	*HLW (0.6-3.0 mbgs)	*
E	18,965	1.7	32,241	*	HLW; red mud tailings (ferric hydroxides); former "poison pond" southeast of EP; rusty brown powdery material in PTB walls; white powder on PTB floor; slag piles west and northwest of the CB	*HLW (0-0.6 mbgs)	*
F	15,002	1.8	27,004	*	HLW; miscellaneous fill on the slope northeast and east of the PTB; building rubble; slightly radioactive gravelly slag material known to be piled on castings building floor	*HLW (0-0.3 mbgs)	*
G	6,154	1.0	6,154	6,154	Low-level radioactive slag pile; limited data below slag pile; pile of greenish grey sandy material at southeast corner of slag pile; former barrel dump containing grey powdery material with blue pellets	Assumed consolidation of 1 m of potential HLW below slag pile	F (WCA)
H	8,286	0.3	2,486	2,486	HLW on north end; MLS; ferric arsenate sludge lagoons constructed on bedrock; unknown volume of sludge comprising a 10-15% concentration of arsenic in the south ferric arsenate sludge lagoon (former north nickel pond); barren solutions were discharged to the former north nickel pond to precipitate metals; low-level radioactive slag around lagoons; former large oil tank	HLW (0.15-0.6 mbgs) on north end	F (WCA)
I	5,572	1.0	5,572	5,572	HLW on north end; MLS; low-level radioactive slag; building rubble; rusty brown material; ferric arsenate sludge	HLW (0-0.3 mbgs)	F (WCA)
J	3,932	0.1	393	393	Limited data; mostly bedrock with thin overburden; former barrel dump; barren solutions were discharged to the former south nickel pond to precipitate metals	Assumed consolidation of 0.1 m of MLS to reduce SEC footprint or potential HLW	E (WCA)
K	14,921	2.2	32,826	32,826	HLW; miscellaneous wastes and impacted fill; dump containing building rubble, ash and silty clay, arsenic laced lime, a white powder, metal debris, wire, wood; low-level radioactive tailings	HLW (0 mbgs-bedrock)	E (WCA)
L	10,906	0.1	1,091	1,091	Limited data; mostly bedrock with thin overburden; HLW at south end in chemical dump containing wastes from a chemical lab, building rubble, old drums and empty sacks of hydrated lime; potential dumping of metallurgical and chemical wastes at the north portion near the plant	Assumed HLW (0-0.3 mbgs) at south end (i.e. one-third of Area L)	F (WCA)
M	14,690	0.5	7,345	7,345	HLW; SSRA identified MLS and metal contamination; chemical dump containing wastes from a chemical lab, building rubble, old drums and empty sacks of hydrated lime; low-level radioactive slag	HLW (0-0.5 mbgs)	F (WCA)
N	22,950	0.3	6,885	6,885	HLW at north end; SSRA identified MLS and metal contamination; Village of Deloro Waste Disposal Site	HLW (0-0.6 mbgs) at north end	D (WCA)
O	7,465	1.0	7,465	7,465	HLW; gold mine tailings from the northwest arm of the Industrial Area; waste rock; green soil on the foundation of the old cyanide mill; light greenish grey powder on foundation of demolished mill	HLW (0-1.0 mbgs)	C (WCA)
P	12,370	0.1	1,237	1,237	Limited data; mostly bedrock with thin overburden	Assumed consolidation of 0.1 m of MLS to reduce SEC footprint or potential HLW	B (WCA)
Q	6,289	2.7	16,980	16,980	HLW; northeast arm of CAA stockpile	HLW (0-4.2 mbgs); CAA in northeast arm of CAA stockpile	B (WCA)
R	3,107	2.4	7,457	7,457	HLW adjacent to powerhouse; former storage area for drums/barrels containing white and green powders	HLW (0-2.4 mbgs) adjacent to powerhouse	B (WCA)
S	5,536	0.1	554	554	Limited data; mostly bedrock with thin overburden	Assumed consolidation of 0.1 m of MLS to reduce SEC footprint or potential HLW	B (WCA)
T	12,473	0.5	6,237	6,237	Limited data; MLS east of hub ruins to consolidate; asbestos sheeting tile dump near kitchen ruins	Assumed consolidation of 0.1 m of MLS to reduce SEC footprint or potential HLW	E (WCA)
U	1,619	0.1	162	162	Limited data; mostly bedrock with thin overburden	Assumed consolidation of 0.1 m of MLS to reduce SEC footprint or potential HLW	E (WCA)
V	7,491	2.0	14,982	14,982	Limited data; MLS; miscellaneous fill on the slope northeast of the PTB; former site reservoir; extensive fill material	Assumed fill materials are potential HLW	F (WCA)
W	15,780	0.1	1,578	1,578	Limited data; mostly bedrock with thin overburden; MLS	Assumed consolidation of 0.1 m of MLS to reduce SEC footprint or potential HLW	E (WCA)
X	5,694	0.1	569	569	Limited data; mostly bedrock with thin overburden; MLS; asbestos sheeting tile dump	Assumed consolidation of 0.1 m of MLS to reduce SEC footprint or potential HLW	E (WCA)
Y	4,251	0.1	425	425	HLW around boarding house ruins; mostly bedrock with thin overburden; dump with empty barrels, slag and asbestos tile sheeting	HLW (0-0.1 mbgs) around boarding house ruins	E (WCA)
Z	7,189	1.5	10,784	10,784	HLW in the central portion; MLS; low-level radioactive slag along the south end; former location of two large oil tanks; scrap metal on west riverbank	HLW (0.6-2.9 mbgs) in the central portion and MLS along the remainder of the Moira River bank to be excavated and rehabilitated; further testing may assist in segregation of MLS and reuse as backfill under SEC instead of in WCA.	B (WCA)
PTB			907	907	Mixture of low-level radioactive slag and potential HLW soil from Village of Deloro stockpiled on PTB floor slab	Assumed HLW unless future testing confirms that soil component is MLS. (If MLS, available for reuse as backfill under SEC)	E (WCA)
MA			32,400	32,400	HLW to be transported from MA to WCA (see Mine Area Closure Plan, CH2M HILL, under development)	HLW	E (WCA)
HLW Subtotals	**244,690**		**294,500**	**164,489**			
Slag			39,426	0	Details of slag volumes located in Areas E, F, G, H, I, M, Z and the MMA are discussed in Section 3.4.1 and Table 3.5	Slag will be placed below SEC as backfill in excavations deeper than 0.65 m as discussed in Section 3.4.1 and Table 3.5	R, Q, V, K
Demolition/Ruins			4,000	0	Demolition of buildings and ruins located on Figure 3-1 in Areas E, F, H, I, L, O, R, T and Y	Reuse as lagoon backfill and as rip/rap for the riverbank reconstruction or other use	H and Z (rip/rap)
Slag, Demolition/Ruins Subtotals			**43,426**	**0**			
Grand Totals			**337,926**	**164,489**			

Notes:
For the purposes of this table, the estimated volume of HLW includes the slag and demolition/ruins, but excludes wastes from Ackerman Conservation Area to be consolidated in Industrial Area

WCA = Waste consolidation area
* = Material already present in WCA
CAA = Calcium arsenate/arsenite
PTB = Primary treatment building
EP = Equalization pond
SEC = Simple Earth (Clay) Cap
HLW = Highly leachable wastes with arsenic concentration >4000 ppm (see Section 3.4.1)
MLS = Marginally leachable soils with arsenic concentration <4000 ppm (see Section 3.4.1)
SLAG = Known stockpiles of slag on the site; excludes unknown volume of non-radioactive slag in Area Y
MA = Mining Area HLW to be consolidated in WCA
CB = Castings Building

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bedrock and is within the 100-year flood boundary. The north nickel pond was temporarily used by the MOE as a sludge storage lagoon with respect to the operation of the ATP but was replaced in 1985. The north nickel pond continues to be retained as an emergency use facility pending revisions to the sludge management system as part of the site cleanup.

Laboratory Wastes

Metallurgical and chemical wastes from the chemistry and research laboratories were thought to have been dumped adjacent to these laboratories, with small volumes of toxic materials placed in a "poison pond" located to the west of the PTB and south of the calcium arsenate/arsenite stockpile. The "poison pond" was located adjacent the southeast corner of the equalization pond in Area E.

The laboratory wastes are likely to be located in the fill materials at the north end of Area L or at the south end of Area L in the dump.

Arsenic Compounds

Calcium Arsenate/Arsenite. A calcium arsenate/arsenite stockpile was identified in Areas B and Q to approximately 4.1 metres below ground surface (mbgs), in an area that extends approximately 50 m east of the equalization pond and approximately 225 m north of the southeast corner of the equalization pond. Concentrations of arsenic in the calcium arsenate/arsenite stockpile have been found to exceed 400,000 ppm.

Speciation studies on the white powdery material (previously reported to be calcium arsenite) stockpiled to the east of the equalization pond identified it to be comprised of both calcium arsenate and calcium arsenite minerals, forming 20 to 65 percent of the stockpile material (CH2M HILL, December 2003b). Calcium arsenate almost exclusively dominates the upper part of the stockpile (47 to 60 percent), while calcium arsenite dominates the intermediate and deeper part of the stockpile material (20 to 28 percent). Calcium plus magnesium carbonate minerals form almost all of the remaining mineralogy.

The pile has been covered by a thin (approximately 100 mm) layer of crushed slag to reduce wind erosion; however, the cover layer is discontinuous, and the white powder is exposed to the elements in several areas.

In addition to calcium arsenate, the following arsenic-bearing compounds and their mineral names, if known, were identified in the stockpile:

- $Ca_3(AsO_4)_2 \cdot 11H_2O$ - Phaunouxite
- Ca-As-O - Calcium arsenite
- $(H_3O,Ca)Al_3(SO_4,AsO_4)_2(OH)_6$ - Schlossmacherite
- $Mg_3(AsO_4)_2 \cdot 8H_2O$ - Hoernesite
- $Ca_5H_2(AsO_4)_4 \cdot 5H_2O$ - Vladimirite
- $Ca_4(OH)_2(AsO_4)_2 \cdot 4H_2O$

Calcium arsenate and calcium arsenite both have relatively high solubilities. Rainfall, surface water, or groundwater moving through the minerals would have a highly elevated arsenic concentration and likely leave a variable amount of calcium carbonate behind, depending on the amount of bicarbonate/carbonate in the influent water. The portlandite identified in two of the analyzed samples may be reflecting this process, but it could also have been formed during the conversion of arsenic trioxide to calcium arsenite/arsenate.

Diverting water away from the pile and eliminating water infiltration through the pile material is critical, since water moving out of the perimeter of the pile could have in the order of tens of milligrams per litre of dissolved arsenic. Based on the gelatinous character of at least part of the pile material, it is apparent that water is currently moving into and out of the pile, though likely in small amounts. Therefore, construction of an engineered cover over the stockpile or solidification of this material are appropriate remedial measures.

A white amorphous material was identified in Area Q, north of the slag-covered pile in Area B. A significant 1-m deposit of calcium arsenate/arsenite was found under a 2-m layer of fill at the location of a former dumpsite, the extent of which was proportional to the south arm of the slag-covered calcium arsenate/arsenite stockpile. A thin lens of calcium arsenate/arsenite may also be located in the vicinity of the former cobalt packer house and plant dry building.

Considering the numerous locations where calcium arsenate/arsenite was observed, both above and below ground, it is assumed that the white powdery substance may be present at numerous, unknown discrete locations throughout the Industrial Area.

Other Arsenic-Bearing Wastes. In addition to the calcium arsenate/arsenite wastes, other arsenic-bearing wastes have been identified at the site, including:

- Green/grey arsenic-bearing soil and powder identified in Area G and the north end of Area O in small quantities (less than 2 m^3) on the ground surface
- An estimated 132.4 m^3 of soil excavated during a natural gas line extension in the Village of Deloro between November 15 and 18, 1999, transported to the Industrial Area, and temporarily stored on the PTB floor slab
- Arsenic laced lime was identified in an Area K dump
- A lens of white arsenic-bearing soil was identified along the west bank of the Moira River

These arsenic-bearing wastes will be managed with the other wastes during the waste consolidation activities.

Ferric Arsenate Sludge

The ATP produces approximately 800 m^3/year of red filter cake sludge containing approximately 6 percent to 7.5 percent solids composed mostly of ferric arsenate. The sludge is pumped to the north ferric arsenate sludge lagoon in Area H, where the solids settle and the sludge is dewatered naturally and stored until disposal is arranged.

The southern ferric arsenate sludge lagoon in Area H was taken out of service, but contains an unknown volume of sludge with a 10 to 15 percent concentration of arsenic. The remainder of the sludge is composed of calcium, iron, and chloride.

Ferric Hydroxide Tailings

Ferric hydroxide tailings (red mud) presently exist in Areas C, D, E, and I. The red mud tailings were initially placed in the wetlands within the northwest portion of the Industrial Area (Areas C, N, and O) but were subsequently pumped to the Tailings Area, an impoundment on the east side of the Moira River that covers approximately 8 hectares.

Gold Mine Tailings

Sandy yellow/orange gold tailings consisting of approximately 4.5 percent arsenic, finely ground quartz with sulphur and cyanide, and a mercury concentration of 0.67 mg/L have been identified in Areas C and O, the low-lying wetland areas northwest of the equalization pond.

Low-Level Radioactive Materials

Extensive surveys of the extent and character of the low-level radioactive materials in the Industrial Area of the Deloro site have been conducted by the Atomic Energy Control Board (AECB), (1979[2]), the Ontario Ministry of Labour (MOL), (1986[3]), Golder Associates (Golder, March 1988), and SCIMUS Inc. (CG&S, June 1999). There are two main types of low-level radioactive wastes in the Industrial Area: a tailings-like material and slag. Low-level radioactive slag was also found in the Village of Deloro and transferred to the Deloro Mine Site (CG&S, October 2000).

The approximate pre-cleanup locations of low-level radioactive materials and associated low-level radiation fields (at 1 m above ground surface) in the Industrial Area as well as in the Mine Area, Tailings Area and Young's Creek Area are shown in Figure 3-3. With exception, the low-level radioactive fields, associated with the low-level radioactive slag transferred from the Village of Deloro that is presently stored on the floor of the PTB, are not identified in Figure 3-3 since this material was transferred to the site in 1999 after the site radiation survey was undertaken in 1997 by CH2M HILL.

Additional details on low-level radioactive wastes are provided below.

Low-Level Radioactive Tailings. The low-level radioactive tailings are light brown with a granular consistency similar to that found in uranium tailings. Samples analyzed for radium had concentrations between 16 Bq/g and almost 400 Bq/g. Low-level radiation fields as high as 80 µSv/h on contact were recorded. Between 600 m^3 to 1,200 m^3 of low-level radioactive tailings-like materials were identified in an approximately 1,200 m^2 area near an old lagoon located in Area K.

Low-Level Radioactive Slag. Low-level radioactive slag has been identified in Areas G, H, I, and M, and on the castings building floor in Area F. Low-level radiation fields from the low-level radioactive slag range between 0.5 to 10 µSv/h and radium concentrations have been measured as high as 18.5 Bq/g (CH2M HILL, December 2003a). The majority of low-level radioactive slag appears to be concentrated in two areas on the southeastern and eastern portions of the Area G slag pile, piled on top of other non-radioactive slag. Other major accumulations appear to be around the ferric arsenate sludge lagoons (Areas H and I) and an area to the west of the ATP (Area M). In addition, the slag appears to have been used as fill material throughout the Industrial Area.

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[2] AECB, 05/05/79, referred to in Golder and Associates, *Hydrogeological Investigation Refinery Site Rehabilitation*, 1988, Appendix III.

[3] MOL, 1986, Ontario Ministry of Labour, Field Site Visit, October 7, 1986.

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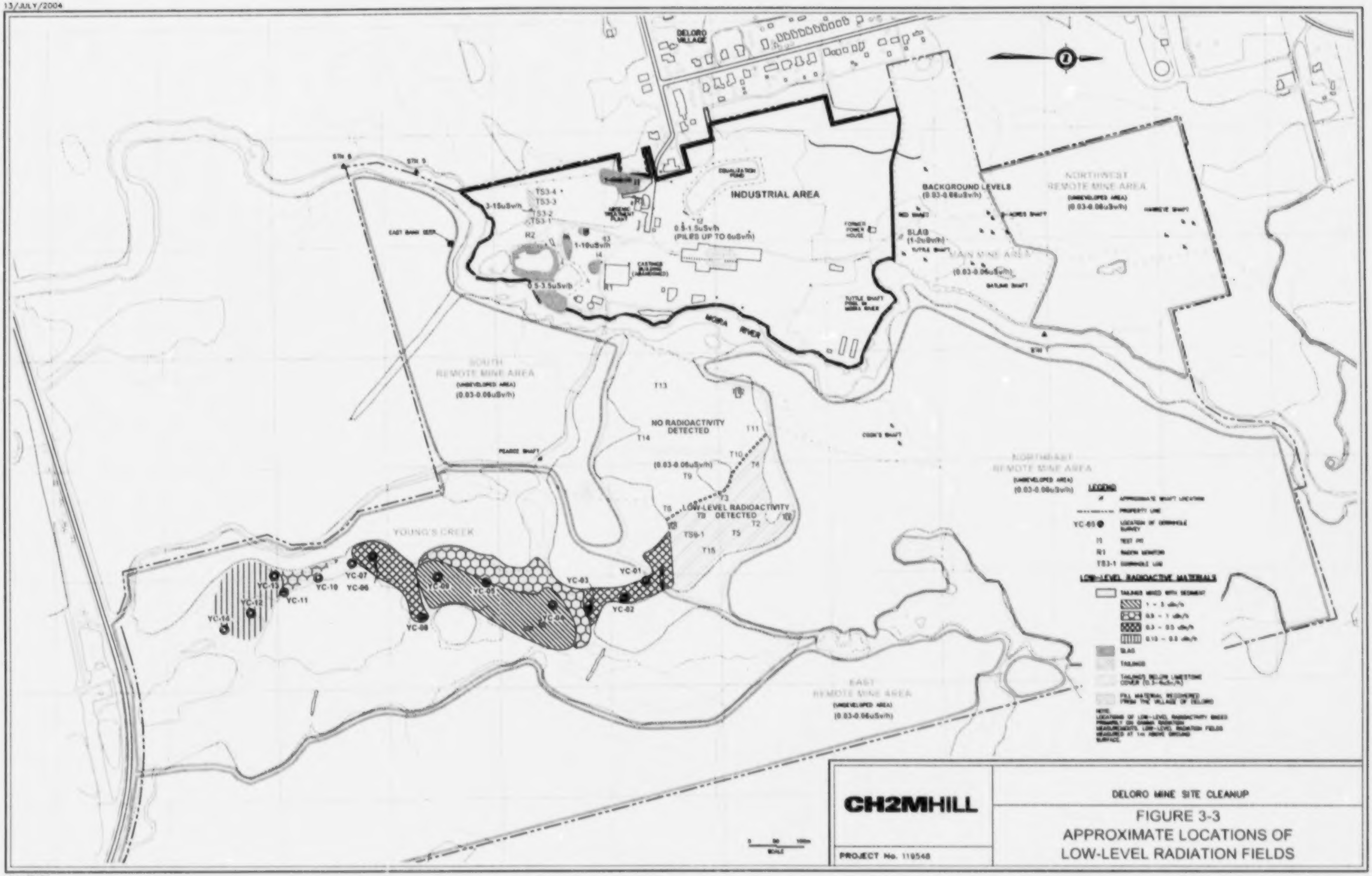
DELORO VILLAGE
INDUSTRIAL AREA
EQUALIZATION POND
0.5-1.5uSv/h
(PILES UP TO 6uSv/h)
FORMER POWER HOUSE
TUTTLE SHAFT
MOIRA RIVER
CASTINGS BUILDING
ARSENIC TREATMENT PLANT
TS3-4
TS3-3
TS3-2
TS3-1
3-15uSv/h
R2
R1
1-10uSv/h
0.5-3.5uSv/h
EAST BANK SEEP
STN 6
STN 5
STN 1
BACKGROUND LEVELS
(0.03-0.06uSv/h)
SLAG
(1-2uSv/h)
MAIN MINE AREA
(0.03-0.06uSv/h)
NORTHWEST REMOTE MINE AREA
(UNDEVELOPED AREA)
(0.03-0.06uSv/h)
SOUTH REMOTE MINE AREA
(UNDEVELOPED AREA)
(0.03-0.06uSv/h)
PEARCE SHAFT
COOK'S SHAFT
NO RADIOACTIVITY DETECTED
(0.03-0.06uSv/h)
LOW-LEVEL RADIOACTIVITY DETECTED
T1
T2
T3
T4
T5
T6
T8
T9
T10
T11
T13
T14
T15
TS6-1
YOUNG'S CREEK
YC-01
YC-02
YC-03
YC-04
YC-05
YC-06
YC-07
YC-08
YC-09
YC-10
YC-11
YC-12
YC-13
YC-14
NORTHEAST REMOTE MINE AREA
(UNDEVELOPED AREA)
(0.03-0.06uSv/h)
EAST REMOTE MINE AREA
(UNDEVELOPED AREA)
(0.03-0.06uSv/h)
LEGEND
APPROXIMATE SHAFT LOCATION
PROPERTY LINE
YC-05
LOCATION OF GAMMA SURVEY
T1 TEST PIT
R1 RADON MONITOR
TS3-1 BOREHOLE LOG
LOW-LEVEL RADIOACTIVE MATERIALS
TAILINGS MIXED WITH SEDIMENT
1 - 3 uSv/h
0.5 - 1 uSv/h
0.3 - 0.5 uSv/h
0.15 - 0.3 uSv/h
SLAG
TAILINGS
TAILINGS BELOW LIMESTONE COVER (0.3-4uSv/h)
FILL MATERIAL RECOVERED FROM THE VILLAGE OF DELORO
NOTE:
LOCATIONS OF LOW-LEVEL RADIOACTIVITY BASED PRIMARILY ON GAMMA RADIATION MEASUREMENTS. LOW-LEVEL RADIATION FIELDS MEASURED AT 1m ABOVE GROUND SURFACE.
0
50
100m
SCALE

CH2MHILL

PROJECT No. 119548

DELORO MINE SITE CLEANUP

FIGURE 3-3
APPROXIMATE LOCATIONS OF
LOW-LEVEL RADIATION FIELDS

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An estimated 774.4 m^3 of low-level radioactive slag mixed with potentially highly leachable soil was excavated from four locations in the Village of Deloro between November 29 and December 2, 1999, transported to the Industrial Area, and temporarily stored on the PTB floor slab (CG&S, October 2000). The slag and potentially highly leachable soil will be consolidated as highly leachable waste (HLW) in the WCA unless additional analyses indicate that the soil is not highly leachable. If the soil is found to be marginally leachable, it would be reused as backfill under the simple earth (clay) cap.

Non-Radioactive Slag

The by-product of the smelting and refining process, the non-radioactive slag is a hard glass-like material comprising cobalt (1 percent), arsenic (0.11 to 1.03 percent), and traces of calcium, silicates, and iron. A large quantity of non-radioactive slag is present in the ridge to the west of the castings building in Area E and may also be present on the west bank of the Moira River (Area Z) in the central portion of the Deloro Mine Site and other fill locations. There are 32-200 L drums of cobalt ore/slag (~6 m^3) and a slag pile (~3 m^3) in the castings building in Area F. In addition, there is an unknown, though likely minor, quantity of slag on the ground surface in Area Y near the former boarding houses.

Ackerman Conservation Area Wastes

A study (Golder, May 1995) of the soil and fill quality at the Ackerman Conservation Area identified HLW and marginally leachable soil (MLS). The Ackerman property, which includes the former Ackerman Mine Site, is located south of the Deloro Mine Site on the south side of Highway 7 (see Figure 1-2). The MOE is working with the Moira River Conservation Authority (MRCA) c/o Quinte Conservation (QC) on a permanent environmental solution, which involves excavation and transportation of the contaminated materials to the Deloro site from the Ackerman property, and consolidation within the Industrial Area. Determination of waste volumes associated with the Ackerman property is beyond the scope of this Closure Plan and the waste volumes have not been included in Table 3.2.

3.3.4 Waste Removal and Handling

The majority of the soil and waste handling will be performed using heavy equipment, namely excavators and trucks.

All excavation work and trenching, if necessary, will be carried out in accordance with the provincial *Regulations for Construction Projects*. Excavations below 5 m depth are not anticipated for the Industrial Area rehabilitation program.

The bedrock at the site is a relatively unweathered, sparsely fractured and highly resistant Precambrian metavolcanic and metasedimentary rock. At present, rock excavations, and therefore blasting, will not be required in the Industrial Area. When excavations extend to bedrock, the bedrock may remain exposed provided the grade of the bedrock is suitable to the surrounding area. Figure 3-2 identifies significant bedrock outcrops in Areas J, L, P, S, U, W, X, and Y.

The low-level radioactive and non-radioactive slag stockpiled or deposited in the Industrial Area has been determined to exhibit low leaching potential and is not considered to be bioavailable. In addition, the draft SSRA (CH2M HILL, May 2003b) indicates that a minimum 45-cm cap over low-level radioactive constituents at the site will reduce low-level radiation fields to background levels. Therefore, the slag will be reused as backfill in excavations deeper than 65 cm. The low-level radioactive slag will require an approximately 65-cm thick simple earth (clay) cap to reduce low-level radiation at surface to background levels. In some cases, the slag materials consist of monolithic, glass-like deposits and may need to be managed and covered in place if such materials cannot be readily excavated.

The removal and handling of the calcium arsenate/arsenite in Area Q to Area B and stockpiles of low-level radioactive materials warrant special attention due to the following conditions:

- The calcium arsenite in the deeper parts of the Area B stockpile is more toxic than calcium arsenate. Therefore, the calcium arsenate/arsenite in Area Q and elsewhere should be treated with caution, since it is not possible to visually distinguish between the two types of materials.
- Biota, particularly fungi, derive energy from the conversion of arsenic to methylated arsine gases. Therefore, the calcium arsenate/arsenite material should not be stored or handled in enclosed spaces due to the possibility of the generation of methylated arsine gas (CH2M HILL, December 2003b).
- The low-level radioactive tailings in Area K are likely to be leachable and therefore will be excavated and consolidated under the engineered cover. Strict controls for low-level radiation hazards, low-level radioactive contamination, dust generation and sediment transport during storm events must be implemented during the excavation, hauling, and placement of the low-level radioactive tailings-like material.
- The low-level radioactive and arsenic constituents in the low-level radioactive slag are considered to be immobile and not bioavailable, and therefore represent a hazard only from low-level radiation fields. Contaminant and dust control are not expected to be significant issues.

Stormwater from rainfall events, especially heavy rainfall during storms, can result in the migration of contaminated materials during excavation and waste placement activities. The contaminants can be transported in eroded sediments as suspended or dissolved solids in the stormwater to nearby watercourses. Surface water protection controls will be in place to minimize sediment migration in stormwater. In addition, stormwater controls are necessary to prevent the accumulation of ponded water in work areas, which can reduce work efficiency.

Excavations will be staged such that grades permit the egress of stormwater to a catchment area or temporary retention pond to collect stormwater for sampling, sediment settling, and – depending on the water quality – release to the Moira River or the equalization pond for processing in the ATP. Potential locations for temporary retention ponds in the Industrial Area include the former south nickel pond, the equalization pond, or Areas C, N, or O (the lower lying area northwest of the equalization pond).

Dust, noise, surface water protection, and decontamination procedures are presented in Section 4.7.

3.3.5 Waste Transportation

Waste transportation in the Industrial Area will largely be confined to the excavation and consolidation of wastes within the Industrial Area. Worker health, community health, and environmental protection will be considered in the transportation of wastes at the site.

Special contamination control measures will be implemented during the transport of the low-level radioactive tailings-like material.

A Transportation and Emergency Response Plan (TERP) will be developed for the project to identify emergency contacts; emergency procedures in the event of accidents, spills, etc.; primary haul routes; truck tarping; decontamination procedures; and other issues associated with the transportation of contaminated and non-contaminated waste/soil at the site.

Although materials will be excavated and transported to the Deloro site from the Ackerman property and consolidated within the Industrial Area, discussions regarding this process are beyond the scope of this Closure Plan.

3.3.6 Waste Conditioning

At present, waste materials identified in the Industrial Area will not require processing. The need to condition wastes may arise at a future date and will be addressed at that time.

3.4 Waste Isolation and Containment

The conceptual remediation method that was recommended for the majority of the Industrial Area is the excavation and consolidation of the most contaminated materials (i.e. HLW) in one portion of the site with the construction of an engineered cover over that portion, and a simple earth (clay) cap over the remaining less contaminated (i.e. MLS) areas of the site.

The primary goals of this method are to minimize:

- Contact between surface water runoff and the wastes
- Infiltration of precipitation into the wastes
- Subsequent contaminant leaching and migration to the Moira River
- Offsite migration of contaminants by wind transport
- Human health and ecological risks

3.4.1 Design Description

To meet the site closure objectives, the design of the recommended alternative was based on minimizing the footprint of HLW in the Industrial Area, human and ecological contact, surface water and stormwater infiltration, erosion of the wastes, and groundwater contact with the wastes.

Site Preparation

Prior to commencing the remediation work, site preparation work will be completed that includes establishment of controls protective to the environment and human health, mobilization of equipment (excavators, trucks, site trailers, and other equipment), construction of access roads, clearing and grubbing of the land, and establishment of temporary services such as site trailers, utilities and a decontamination pad.

As the rehabilitation program will span several years, certain site preparation tasks will be duplicated every year, including the mobilization and demobilization of equipment and trailers. Clearing and grubbing of the land will be conducted on areas that are to be affected by construction activities that year. Trees may be mulched and reused on the site as cover.

Waste Consolidation

The objectives of waste consolidation are to reduce the footprint of HLW and significantly reduce the leachate generating potential of the wastes to groundwater and surface water.

The Industrial Area covers approximately 244,690 m^2 (approximately 25 ha) of land and for the purposes of this Closure Plan has been divided into five distinct regions: the Equalization Pond (Area A), the WCA (Areas B to F), the South Industrial Area (Areas G to M), the North Industrial Area (Areas N to Y), and the Riverbank Reconstruction Area (Area Z). Areas A to Z are identified in Figure 3-2.

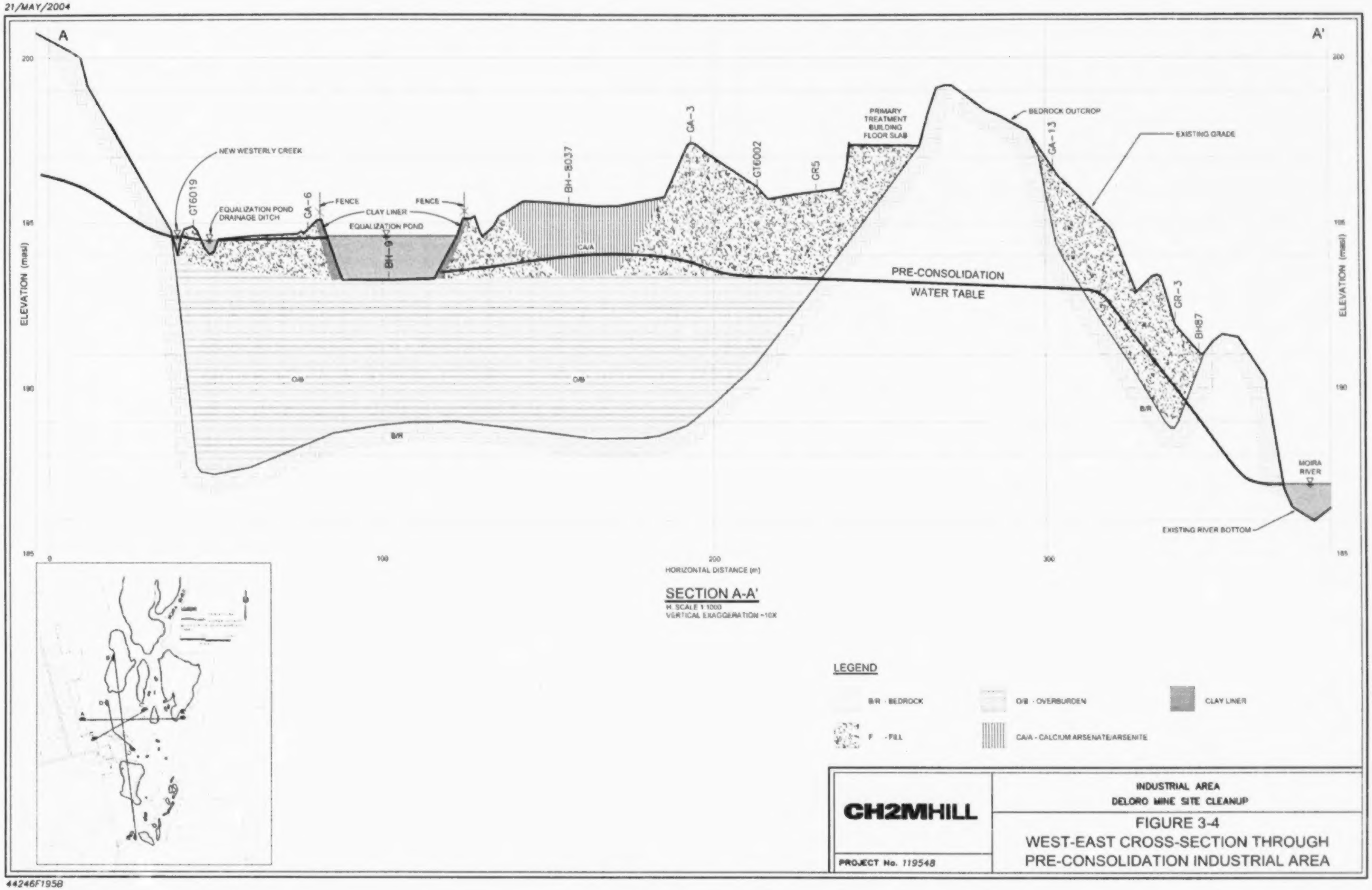
It has been estimated that the Industrial Area contains approximately 460,000 m^3 of non-contaminated and contaminated soil (fill and overburden) above the bedrock. For the purposes of this Closure Plan, it has been conservatively assumed that all the soil above the bedrock in the Industrial Area is at least partially contaminated. As a result, the groundwater simulations of the GIWN undertaken to date, including the 2004 modelling results (Appendix A), have been based on the conservative objective of fully dewatering the surficial deposits.

Figures 3-4 and 3-5 present cross-sections A-A' and B-B' of the existing Industrial Area soil conditions and site grading. These cross-sections show that within the majority of the Industrial Area, there is a native silty-clay deposit of up to approximately 3.5 m in thickness beneath the contaminated wastes and fill materials. While the silty-clay deposit, as well as a thin sand and gravel deposited on bedrock (where present), have also become contaminated through leaching and migration of contaminated groundwater, the concentrations of arsenic and other metals are significantly less than present in the overlying contaminated wastes and fill materials. It is likely that the majority of the contaminant loading to groundwater is through direct contact of the groundwater with leachable wastes, which typically occur above the silty-clay material. Therefore, there may not be a need to fully dewater the surficial deposits, if significant improvement in groundwater quality can be achieved by sufficiently lowering groundwater elevations to minimize direct contact of the leachable wastes with groundwater.

Therefore, as recommended in Section 2.2.2, depending on the data obtained during the upcoming hydrogeological field program, additional modelling should also include evaluation of a horizontal well constructed entirely in the overburden, in conjunction with vertical pressure relief wells constructed in the bedrock, to determine if effective groundwater flow control can be achieved. Depending on the results of these evaluations, this may potentially lead to a more cost-effective GIWN than the cost opinion presented in Section 4.5 (based on a horizontal well in bedrock and vertical pressure relief wells to completely dewater the surficial deposits beneath the WCA).

A waste classification study (Golder, July 1988) on various wastes at the site (e.g. gold tailings, red mud, calcium arsenite, ferric arsenate sludge) indicated that there was little correlation between arsenic concentration in soil and the leachate toxicity of the soil. The lowest arsenic concentration of the various non-leachate toxic wastes analyzed was 4,400 ppm. Therefore, CH2M HILL has conservatively designated HLW as wastes with arsenic concentrations exceeding 4,000 ppm, and MLS as wastes with arsenic concentrations less than 4,000 ppm. This conservative assumption is further supported by samples analyzed for arsenic and leachate toxicity on the Ackerman Conservation Area (Golder, May 1995).

21/MAY/2004


A
A'
ELEVATION (masl)
200
195
190
185
NEW WESTERLY CREEK
GT6019
EQUALIZATION POND DRAINAGE DITCH
GA-6
FENCE
CLAY LINER
FENCE
EQUALIZATION POND
BH-9
BH-B037
CA/A
GA-3
GT6002
GR5
PRIMARY TREATMENT BUILDING FLOOR SLAB
BEDROCK OUTCROP
GA-13
EXISTING GRADE
PRE-CONSOLIDATION WATER TABLE
GR-3
BH87
O/B
O/B
B/R
B/R
MOIRA RIVER
EXISTING RIVER BOTTOM
0
100
200
300
HORIZONTAL DISTANCE (m)
LEGEND
B/R - BEDROCK
F - FILL
O/B - OVERBURDEN
CA/A - CALCIUM ARSENATE/ARSENITE
CLAY LINER

SECTION A-A'
H. SCALE 1:1000
VERTICAL EXAGGERATION ~10X

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INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

FIGURE 3-4
WEST-EAST CROSS-SECTION THROUGH PRE-CONSOLIDATION INDUSTRIAL AREA

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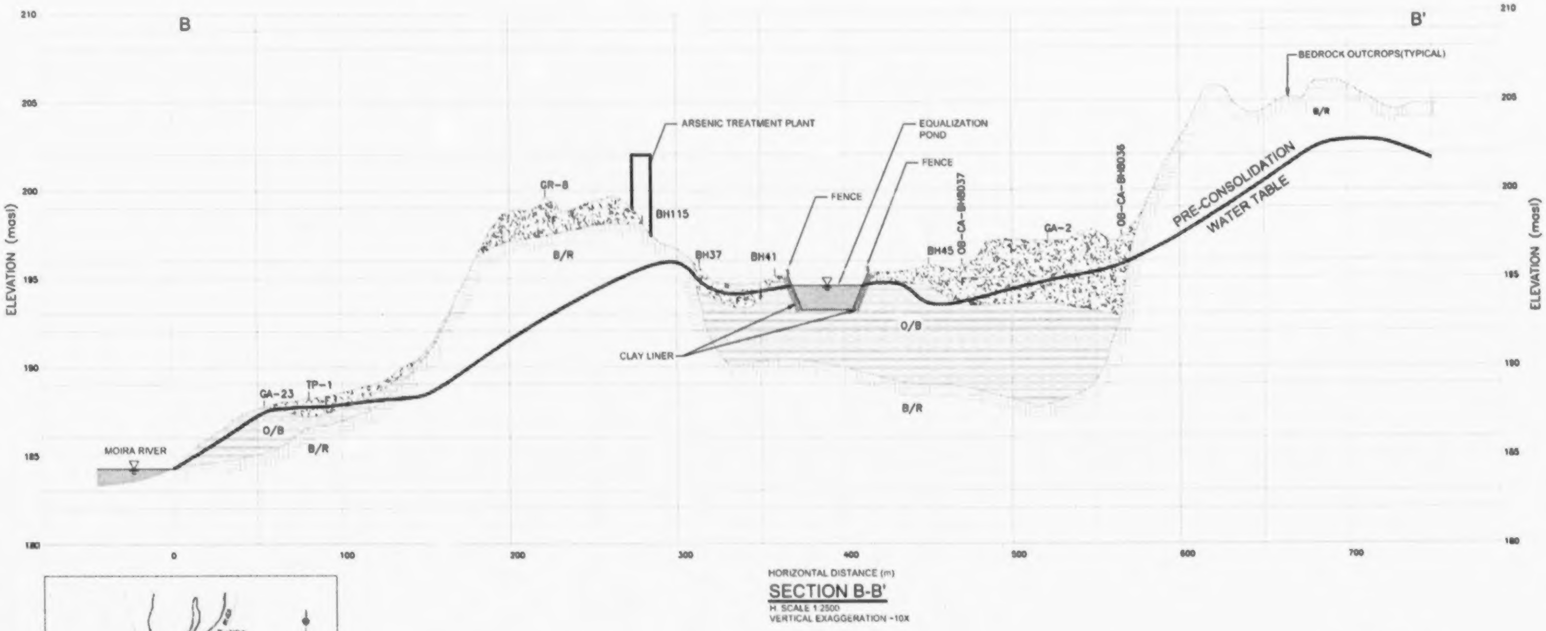
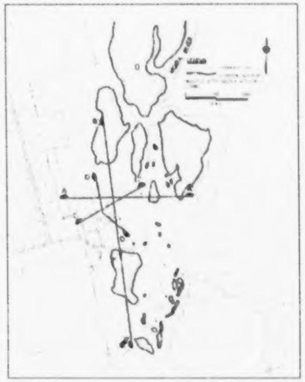

210
205
200
195
190
185
180
ELEVATION (masl)
B
B'
BEDROCK OUTCROPS(TYPICAL)
B/R
ARSENIC TREATMENT PLANT
EQUALIZATION POND
FENCE
FENCE
GR-8
BH115
B/R
BH37
BH41
BH45
OB-CA-BH8037
GA-2
OB-CA-BH8036
PRE-CONSOLIDATION WATER TABLE
O/B
CLAY LINER
B/R
GA-23
TP-1
O/B
B/R
MOIRA RIVER
0
100
200
300
400
500
600
700
HORIZONTAL DISTANCE (m)

SECTION B-B'
H. SCALE 1:2500
VERTICAL EXAGGERATION ~10X



LEGEND

- ▤ B/R - BEDROCK
- ▨ F - FILL
- ☰ O/B - OVERBURDEN
- ■ CLAY LINER

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INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

FIGURE 3-5
SOUTH-NORTH CROSS-SECTION THROUGH PRE-CONSOLIDATION INDUSTRIAL AREA

44246F20H

In Table 3.2, the contaminated soil overburden and fill has been categorized as either HLW requiring consolidation under the engineered cover or MLS requiring a simple earth (clay) cap. The exception is the slag on the site, which was determined to be radioactive (low-level) in parts and contains a non-leachable, non-bioavailable form of arsenic. Therefore, the slag will be handled in a different manner than HLW and MLS.

As shown in Table 3.2, the Industrial Area contains approximately 261,200 m^3 of HLW (less the volume on the PTB floor slab or from the Mine Area), approximately 4,000 m^3 of demolition/ruin rubble, approximately 39,426 m^3 of slag, and 907 m^3 of low-level radioactive slag mixed with potentially highly leachable soil from the Village of Deloro that is presently stored on the floor of the PTB. In addition, approximately 32,400 m^3 of HLW will be transported from the Mine Area for consolidation under the engineered cover in the Industrial Area.

Of the approximately 261,200 m^3 of HLW in the Industrial Area, approximately 130,000 m^3 presently resides in deposits within the WCA (Areas B to F). Some of the demolition/ruin rubble might be reused as rip/rap along the Moira River bank provided it is not contaminated. The slag will be used as backfill in the deeper excavated areas to the north and south of the proposed WCA.

The remaining approximately 131,200 m^3 of HLW located in Areas G to Z (includes radioactive tailings in Area K) and the slag/potential highly leachable soil on the PTB floor (907 m^3), and the HLW to be transported from the Mine Area (32,400 m^3), will require consolidation in Areas B to F. (If future testing confirms the soil component on the PTB floor is MLS, it will be used as backfill under the simple earth [clay] caps.) The engineered cover will be placed over approximately 164,500 m^3 of HLW. Additional waste materials identified during construction work will be similarly consolidated.

Through the excavation and consolidation of approximately 131,200 m^3 of HLW from the riverbank and north and south Industrial Areas, the footprint of HLW will be reduced from approximately 236,700 m^2 (excludes Area A, the equalization pond) to approximately 60,000 m^2. During the final design, a three-dimensional model of the WCA will be required to refine the volume of HLW that can be consolidated in the area, the grading of the WCA and the final dimensions of the WCA footprint. In the event that the three-dimensional model indicates that the WCA has insufficient volume to store all of the identified HLW; areas N, Q, T, and G have been identified as potential waste consolidation expansion areas. Table 3.3 identifies the estimated area of the distinct Industrial Area regions and the estimated volume of HLW in each distinct region.

TABLE 3.3
HIGHLY LEACHABLE WASTE IN THE DISTINCT REGIONS OF THE INDUSTRIAL AREA

Distinct Region of the Industrial Area	Areas in Distinct Region	Area of Region (m^2)	HLW in Region (m^3)
Equalization Pond	A	7,993	–
Waste Consolidation Area	B to F	60,022	130,011
South Industrial Area	G to M	64,461	55,867
North Industrial Area	N to Y	105,025	64,531
Riverbank Reconstruction Area	Z	7,189	10,784
Total		**244,690**	**261,193**

It is not the intention of the rehabilitation program to remove and consolidate all of the Industrial Area contaminated soils (HLW and MLS) under an engineered cover, as there is insufficient space in the Industrial Area. Therefore, the underlying MLS, if present, will remain in place following the excavation and consolidation of HLW under the engineered cover. Excavation and consolidation of areas of thin, discontinuous MLS overlying bedrock will be conducted to eliminate the requirement for a simple earth (clay) cap in these areas.

The excavated portions of the Industrial Area will be backfilled to an appropriate grade that facilitates the placement of a simple earth (clay) cap to cover approximately 198,810 m^3 of MLS and slag remaining above the bedrock in the Industrial Area to the north and south of the engineered cover. The design of the simple earth (clay) cap is appropriate for MLS and is discussed in further detail below.

Excavations that extend to bedrock may remain exposed provided the grade of the bedrock is suitable to the surrounding area. All bedrock outcrops within the WCA will be covered with an engineered cover. Therefore, simple earth (clay) caps will not be required for Areas J, L, P, S, U, W, X, and Y, which occupy an area of approximately 60,088 m^2. In addition, it has been estimated that there is approximately 2,000 m^2 of smaller exposed bedrock outcrops, mostly located in Areas I, T, V, and Z. Exposed bedrock in Areas I, T, and V will not require a simple earth (clay) cap, unless slag is backfilled into these areas. It will be determined prior to the riverbank reconstruction program whether exposed bedrock outcrops in Area Z will be covered or remain exposed. Figure 3-6 identifies the estimated extent of the engineered cover and the simple earth (clay) caps in relation to the bedrock outcrops and riverbank reconstruction.

Consolidation, grading, and covering/capping of the Industrial Area will affect existing pumping stations, inspection holes, monitoring wells, and the overland forcemain from the Tuttle Shaft. The pumping stations, inspection holes, and wells will require modification to extend these to the new final grade. The existing forcemain from the Tuttle Shaft will be replaced with a new above ground pipeline as detailed in the Mine Area Closure Plan (CH2M HILL, under development).

The detailed schedule of waste consolidation is provided in Section 4.4.

Engineered Cover Installation

An engineered cover will be placed over the consolidated wastes:

- To minimize the infiltration of precipitation through the HLW and into the underlying groundwater
- To prevent exposure of HLW to human and ecological receptors
- To eliminate surface water runoff on the HLW, and HLW sediment migration to the Moira River

The design and placement of the engineered cover are discussed below.

Treed Cover Design. The design criteria for the engineered cover required the development of a specific soil profile that is capable of supporting plant life as well as providing hydraulic control of infiltration. The design basis of a poplar tree cover system is to manage water and reduce and/or eliminate deep percolation of precipitation through the engineered cover. The cover design proposed for the Industrial Area incorporates moisture retention layers to hold

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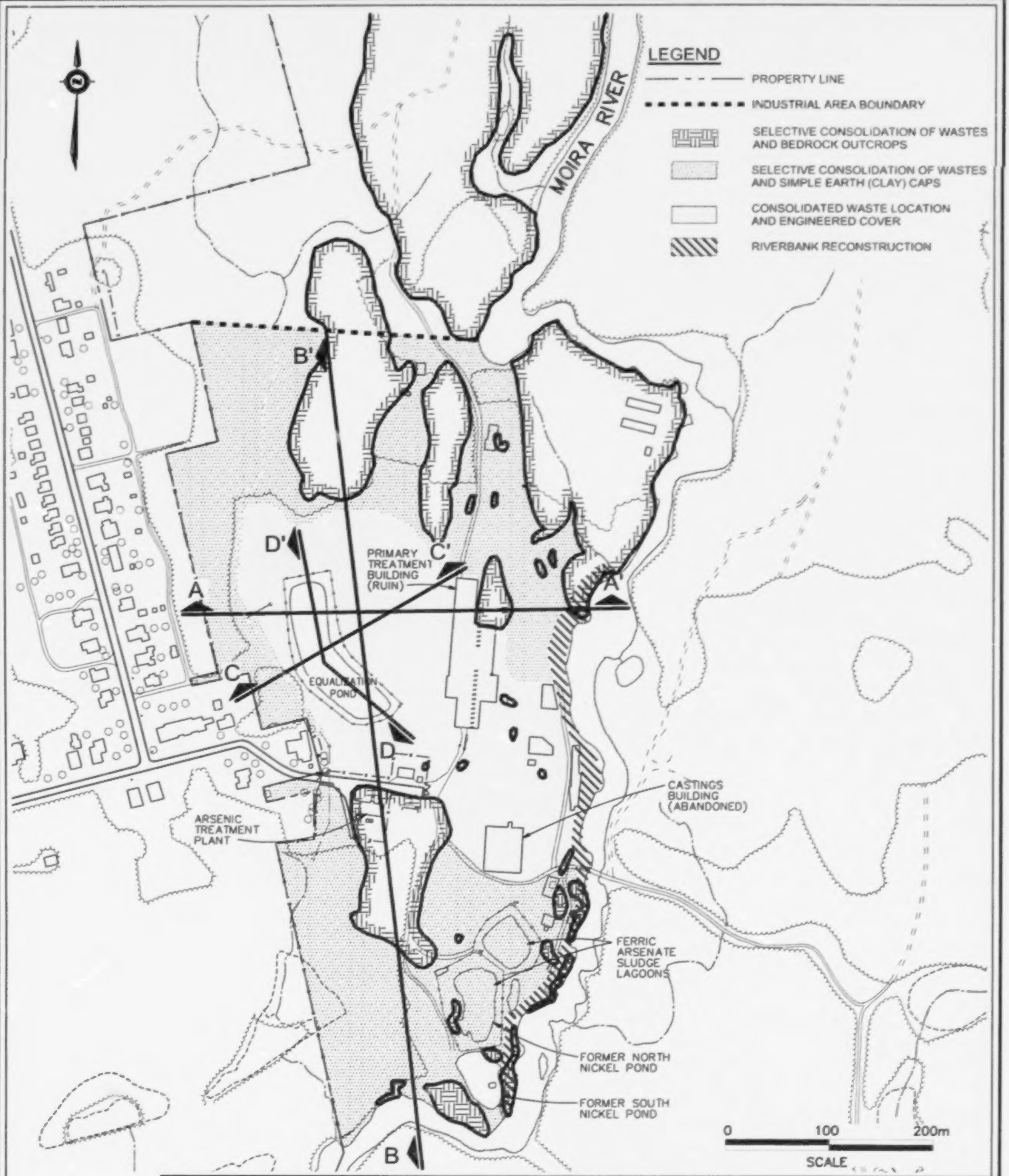
LEGEND
PROPERTY LINE
INDUSTRIAL AREA BOUNDARY
SELECTIVE CONSOLIDATION OF WASTES AND BEDROCK OUTCROPS
SELECTIVE CONSOLIDATION OF WASTES AND SIMPLE EARTH (CLAY) CAPS
CONSOLIDATED WASTE LOCATION AND ENGINEERED COVER
RIVERBANK RECONSTRUCTION
N
MOIRA RIVER
A
A'
B
B'
C
C'
D
D'
PRIMARY TREATMENT BUILDING (RUIN)
EQUALIZATION POND
ARSENIC TREATMENT PLANT
CASTINGS BUILDING (ABANDONED)
FERRIC ARSENATE SLUDGE LAGOONS
FORMER NORTH NICKEL POND
FORMER SOUTH NICKEL POND
0
100
200m
SCALE

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FIGURE 3-6: LOCATION OF CONSOLIDATED WASTES, ENGINEERED COVER AND SIMPLE EARTH (CLAY) CAPS

44246F27C

excess percolation until it can be taken up by means of evapotranspiration during the summer growing season by the trees. It also includes barrier layers to prevent vertical flow and a drainage layer.

The cover will have a high runoff coefficient to minimize infiltration and saturation of the upper layers during spring runoff and times of heavy precipitation. Early tree growth in May creates unsaturated zones within the cover and forms a barrier to new infiltration. Rapid growth during the warm, dry summer months then extends the unsaturated zones to the entire cover. Infiltration from autumn precipitation is absorbed and held by soil suction throughout the winter months when no infiltration occurs.

The treed cover concept takes advantage of the tremendous potential water uptake capability of hydrophilic tree species such as the locally common poplar and red maple. Data from modelling undertaken by CH2M HILL for the Deloro site indicate that, when planted at an average density of one tree per 3 m^2, poplar have the potential to evapotranspire up to 633.8 mm of water in a growing season running from April to November (CH2M HILL, May 2002). Average annual precipitation in the Deloro area is approximately 900 mm; therefore, theoretically, a treed cover has the potential to evapotranspire most of the annual infiltration.

In reality, trees do not reach their potential evapotranspiration because of soil moisture deficit conditions during the dry summer months, and some infiltration occurs because precipitation is not evenly distributed throughout the growing season.

CH2M HILL has refined the engineered cover design model to incorporate the treed cover concept. CH2M HILL utilized the U.S. Environmental Protection Agency's Hydrologic Evaluation of Landfill Performance (HELP) model, Version 3.07, for its evaluation of poplar tree cover systems in northern climates. The modelled design of the poplar tree cover system included the soil profile layers in Table 3.4, except the geosynthetic clay liner (GCL), which has been added to augment the modelled cover design.

TABLE 3.4
ENGINEERED COVER DESIGN

Soil Layer	Depth (cm)	Rationale
Upper Soil Profile	Primarily intended to support the poplar trees and provide water storage capacity	
Silty Loam Topsoil	15	Provides the initial rooting medium and the necessary nutrients, organic material, and trace metals for initial plant growth
Silty clay loam	35	Provides soil moisture storage capacity during the non-growing season and facilitates deeper rooting
Lower Soil Profile	Further minimize percolation, permit drainage and provide additional storage capacity to increase the effectiveness of the cover during non-growing season	
Compacted Clay	30	Acts as a restrictive barrier layer to minimize percolation of water into the underlying drainage layer
Sand	25	Acts as a water collection, storage, and transport system for water that penetrates the upper layers especially during the non-growing season. Collected water is diverted away from the remainder of the engineered cover and the Industrial Area
Geosynthetic Clay Liner	NA	Forms a secondary infiltration barrier of the engineered cover
Compacted Clay	50	Acts as a secondary restrictive barrier layer to minimize percolation of water into the underlying waste

A profile of the engineered cover over HLW is depicted in Figure 3-7.

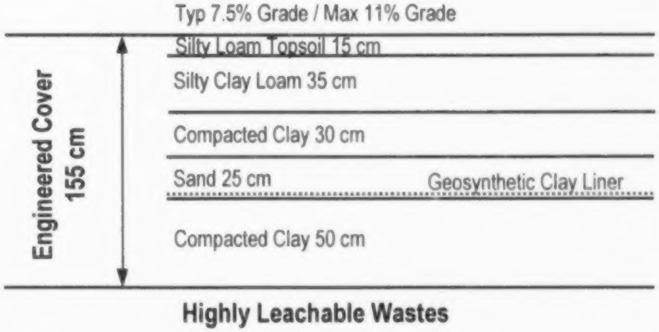
Typ 7.5% Grade / Max 11% Grade
Silty Loam Topsoil 15 cm
Silty Clay Loam 35 cm
Compacted Clay 30 cm
Sand 25 cm
Geosynthetic Clay Liner
Compacted Clay 50 cm
Engineered Cover
155 cm
Highly Leachable Wastes

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Figure 3-7
Profile of Engineered Cover over Highly Leachable Wastes

The HELP model simulation results suggest that:

- Approximately one-third of the annual precipitation leaves the area as surface runoff
- Almost two thirds of the annual precipitation leaves the area via evapotranspiration through the trees
- Only about 4 percent of the annual precipitation percolates into the lower soil profile
- The HELP model simulated an average annual reduction in percolation of 97.33 percent
- The percolation into the waste is extremely low but not zero.

The topsoil components must have an effective volumetric moisture storage capacity (difference of at least 15 percent between field capacity and wilting point) and an in-place hydraulic conductivity of greater than 1×10^{-5} cm/s.

The clay component of the cover should have an in-place hydraulic conductivity lower than 1×10^{-6} cm/s (ideally 1×10^{-7} cm/s) and be compacted to a minimum of 95 percent standard Proctor maximum dry density (SPMDD) at a near-optimum moisture content.

The sand drainage layer was added to the engineered cover design to provide seasonal water storage and lateral drainage. Volume displacement and head created by over capacity could create adverse conditions for growth of the plantation and compromise the integrity of the clay layer if lateral drainage does not occur. Appropriate grading of the underlying compacted clay layer would initiate the lateral flow of any deep percolation away from the remainder of the engineered cover and the Industrial Area. This flow would not be in contact with the waste material and therefore could be allowed to discharge outside of the Industrial Area without further treatment.

The GCL will be placed over the lower clay layer to form a secondary infiltration barrier of the engineered cover. The GCL's non-woven outer geotextile cover provides high strength in tension and against puncture. The inner layer of sodium bentonite swells under contact with moisture to provide a hydraulic barrier. The barrier is effective in resisting stresses from differential settlement.

The engineered cover design minimizes the risk of mammals burrowing into the underlying wastes, and is at least 1.5 m thick as required by the draft SLERA (Section 2.1.4). Burrows may follow the buried topsoil layer rather than penetrating deeper into the compacted clay and wastes. The treed cover has the potential to evapotranspire water that infiltrates through burrows. It also provides protective cover for common predators such as foxes and coyotes. The presence of these predators will further discourage burrowing in the cover structure.

The cover design may vary slightly, depending on the local availability of cover materials at the commencement of construction activities and the cost of transporting imported cover materials from distant sources. The HELP model will be revisited to address future redesigns of the engineered cover.

Engineered Cover Placement. The engineered cover will be placed over an area of approximately 60,022 m^2.

Initially a clay berm approximately 5-m wide at the base and extending approximately 2 m to an elevation of 197 m, will be constructed around the perimeter of the equalization pond. The mound of HLW will be extended in a radial manner from the equalization pond at a 7.5

to 11 percent grade. As the mounded HLW approaches a grade of 11 percent (maximum), the mound will be progressively covered with a 50 cm layer of clay and compacted to 95 percent SPMDD. This clay is the lowest layer of the engineered cover. At the end of the construction program, when the HLW has been completely consolidated under the lower clay layer, the final layers of the engineered cover will be placed. This approach allows for reworking the dimensions of the mound to accommodate increased HLW volumes and modifications to the mound side slopes with minimal damage to the cover. The top of the 155-cm thick engineered cover will connect to the clay berm at elevation 196.5 m, allowing for a 45-cm swale to divert mound runoff from the equalization pond.

Consolidation of HLW will commence with the riverbank reconstruction wastes, which will be consolidated in Area B, east of the equalization pond adjacent to the clay berm. The low-level radioactive slag mixed with potentially highly leachable soil on the PTB floor will be consolidated in the WCA unless additional analyses indicate that the soil is not highly leachable. The Mine Area wastes should be consolidated in Area B prior to the excavation of wastes and the Mine Area access road, in Areas R and T.

HLW from the North Industrial Area will be consolidated in Areas D, C, B, and the north half of Areas E and F. HLW from the South Industrial Area will be consolidated in the south half of Areas F and E. Areas N, Q, T and G have been designated as a potential extension to the WCA, should quantities of the current WCA (Areas B to F) not have sufficient capacity to accommodate increased volumes of HLW.

The exposed face of the HLW mound will be temporarily tarped using a high-density polyethylene (HDPE) liner of sufficient thickness weighted with sand bags. The mound will be tarped at the end of every workday to prevent exposure, wind transport and sediment runoff during storm events. At the end of each construction season, the mound will either be completely encapsulated in the 50 cm lower clay layer or partially encapsulated with the remaining exposed face covered with the HDPE liner.

The detailed schedule of cover placement is provided in Section 4.4.

Simple Earth (Clay) Cap Installation

A simple earth (clay) cap will be placed over the MLS that will remain following the excavation and consolidation of the HLW. The design objectives for the simple earth (clay) cap are:

- To minimize the infiltration of precipitation through the MLS and into the underlying groundwater
- To prevent exposure of MLS to human and ecological receptors
- To eliminate surface water runoff on the MLS, and MLS sediment migration to the Moira River

The design and placement of various simple earth (clay) cap scenarios are discussed below.

Simple Earth (Clay) Cap Design. The basic design of the 150-cm thick simple earth (clay) cap is:

- 15 cm of topsoil
- 50 cm of compacted clay or other low permeability material
- 85 cm of "clean" or non-leachable, non-bioavailable (e.g. slag) backfill

In Figure 3-8, SEC-1 to SEC-3 depict three variations of the basic simple earth (clay) cap design. In SEC-1, the lower soil profile consists entirely of "clean" fill, likely imported from offsite. In SEC-2, the lower soil profile consists entirely of slag from stockpiles in the Industrial Area. (As previously noted, some of the monolithic slag materials may need to be managed and covered in place if they cannot be readily excavated.) In SEC-3, the stockpiled slag is completely utilized as backfill and "clean" fill is required to complete the lower soil profile to 65 cm below grade. A geotextile filter will be placed over the slag to prevent the migration of fine soils from the upper layers into the void space of the slag.

SEC-4 (Figure 3-8) depicts the required 150 cm of cover over the MLS; however, the design is modified to support vehicular traffic into the site while still maintaining the simple earth (clay) cap design objectives. The SEC-4 design includes:

- 30 cm of Granular 'A' compacted to 98 percent SPMDD
- 55 cm of Granular 'B' compacted to 98 percent SPMDD
- 65 cm of compacted clay or other low permeability material

SEC-4 may be completed at grade with an optional layer of asphalt.

Figure 3-9 provides a profile of the interface between SEC-4, SEC-1, and the engineered cover. This interface only applies to a small portion of the entrance to the site, as the majority of SEC-4 will have exposed bedrock on the south side and the engineered cover on the north. Unlike SEC-1 to SEC-3, SEC-4 includes a partial application of a geosynthetic clay liner (GCL) and subsurface drainage techniques to intercept and divert infiltration. A typical two percent crown on the road surface and one percent crown on the underlying clay layer would assist in minimizing ponded water. The boundary between the granular soils and the engineered cover and SEC-1 will be lined with GCLs and a 100-mm collector tile, to divert percolation through the granular road layers away from the sand drainage layer of the engineered cover and the "clean" fill layer of SEC-1.

Slag Placement. Following the excavation of HLW from the North and South Industrial Area, excavations equal to or deeper than 1.5 m will be considered for the placement of slag. At present these include Areas R, Q, V, and K.

The reuse of slag as backfill (with the possible exception of the monolithic slag) reduces the cost of importing "clean" fill to the site for excavated areas and the cost of specifically placing a simple earth (clay) cap over the slag to prevent exposure to low-level radiation or dust. Excluding the slag stored on the PTB floor slab (see Table 3.2), slag has been identified in Areas E, F, G, H, I, M, and Z occupying an area of approximately 17,004 m^2 and ranging from an estimated 1.0 to 3.1 m in average thickness.

In addition, there are 32-200 L drums of cobalt ore/slag (approximately 6 m^3) and a slag pile (approximately 3 m^3) in the castings building in Area F, and there is an unknown, though likely minor, quantity of slag on the ground surface in Area Y near the former boarding houses. A small quantity of slag (approximately 5 m^3) will be transferred from the Mine Area for reuse as backfill in the Industrial Area.

Table 3.5 identifies the area and volume of slag (approximately 39,426 m^3)available for reuse in the Industrial Area and provides a strategy for the reuse of the slag as excavation backfill.

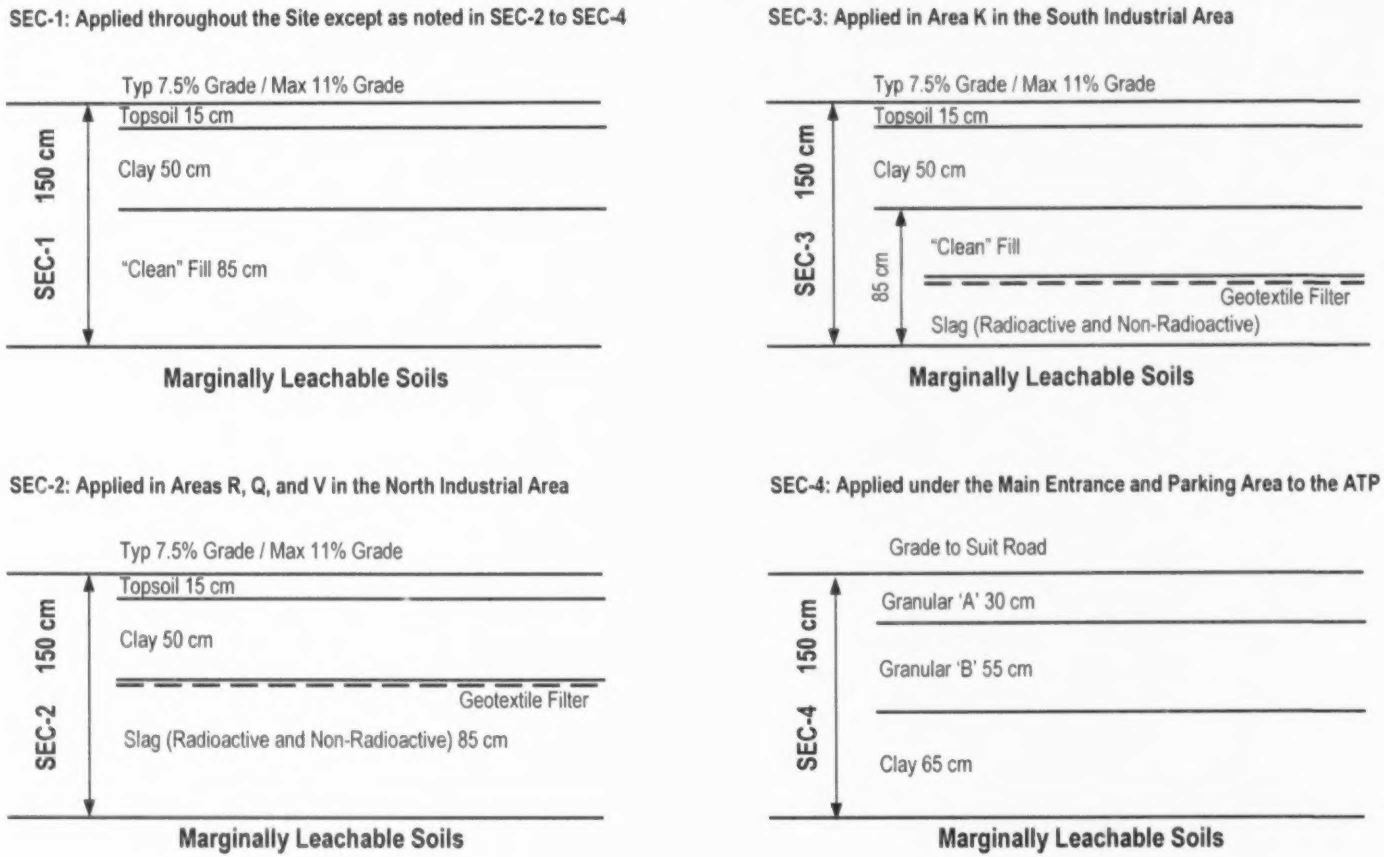
SEC-1: Applied throughout the Site except as noted in SEC-2 to SEC-4
Typ 7.5% Grade / Max 11% Grade
Topsoil 15 cm
Clay 50 cm
"Clean" Fill 85 cm
SEC-1 150 cm
Marginally Leachable Soils
SEC-3: Applied in Area K in the South Industrial Area
Typ 7.5% Grade / Max 11% Grade
Topsoil 15 cm
Clay 50 cm
"Clean" Fill
85 cm
Geotextile Filter
Slag (Radioactive and Non-Radioactive)
SEC-3 150 cm
Marginally Leachable Soils
SEC-2: Applied in Areas R, Q, and V in the North Industrial Area
Typ 7.5% Grade / Max 11% Grade
Topsoil 15 cm
Clay 50 cm
Geotextile Filter
Slag (Radioactive and Non-Radioactive) 85 cm
SEC-2 150 cm
Marginally Leachable Soils
SEC-4: Applied under the Main Entrance and Parking Area to the ATP
Grade to Suit Road
Granular 'A' 30 cm
Granular 'B' 55 cm
Clay 65 cm
SEC-4 150 cm
Marginally Leachable Soils

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Figure 3-8
Profiles of Simple Earth (Clay) Caps (SEC-1 to SEC-4)
over Marginally Leachable Soils

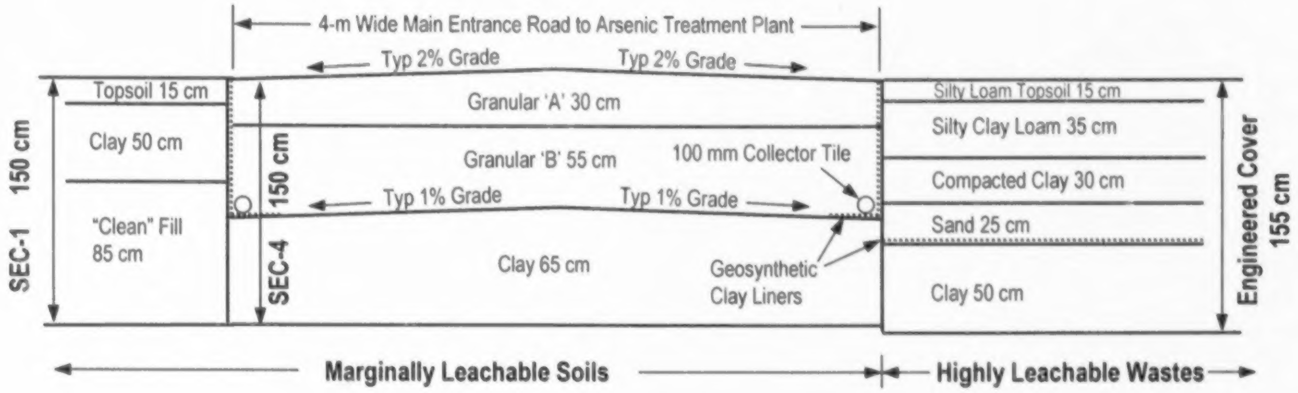
4-m Wide Main Entrance Road to Arsenic Treatment Plant
Typ 2% Grade
Typ 2% Grade
Topsoil 15 cm
Clay 50 cm
"Clean" Fill
85 cm
SEC-1
150 cm
SEC-4
150 cm
Granular 'A' 30 cm
Granular 'B' 55 cm
100 mm Collector Tile
Typ 1% Grade
Typ 1% Grade
Clay 65 cm
Geosynthetic
Clay Liners
Silty Loam Topsoil 15 cm
Silty Clay Loam 35 cm
Compacted Clay 30 cm
Sand 25 cm
Clay 50 cm
Engineered Cover
155 cm
Marginally Leachable Soils
Highly Leachable Wastes

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Figure 3-9
Profile of SEC-4 Interface with SEC-1 and Engineered Cover at Main Entrance Road

119548ES210204_E032004021KWO

Table 3.5
Slag Inventory and Strategy for Reuse as Backfill

Area I.D.	Surface Area of Slag (m^2)	Mean Depth of Slag (m)	Approx. Volume of Slag (m^3)	Strategy for Reuse of Slag as Excavation Backfill *
MA	-	-	5	Temporary transfer to Area G to accommodate the Mine Area rehabilitation
F - CB pile	-	-	3	Temporary transfer the pile of cobalt ore/slag from CB to Area G prior to CB demolition
F - CB drums	-	-	6	Temporary transfer the 32 - 200 L drums of gravelly slag from CB to Area G prior to CB demolition
Z	1,250	1.0	1,250	Temporary transfer to Area G to accommodate the riverbank reconstruction program
Y	-	-	?	Temporarily transfer unknown quantity of non-radioactive slag from boarding house ruins to Area G
H	1,500	1.0	1,500	Transfer to Area R
M	2,100	2.0	4,200	Transfer 3,937 m^3 to Area R and 263 m^3 to Area Q
E	3,750	3.1	11,750	Transfer to Area Q
I	2,250	1.0	2,250	Transfer 880 m^3 to Area Q and 1,370 m^3 to Area V
G	6,154	3.0	18,462	Transfer 8,743 m^3 to Area V, 9,719 m^3 to Area K, then the 1,264 m^3 of temporarily stored MA, Area F and Area Z slag to Area K
Grand Totals	**17,004**		**39,426**	

Notes:

* Strategy for slag reuse is based on the estimated available volumes in the excavations listed in Table 3.2. Scheduling changes will affect the reuse strateg

CB = Castings Building

MA = Mining Area slag to be used as backfill in IA

? = Unknown quantity, though likely minor, of non-radioactive slag in Area Y

At present, it is estimated that there will be approximately 51,570 m^3 of excavation space below an excavation depth of 0.65 mbgs available for slag backfill, including:

- Approximately 5,437 m^3 available for slag backfill in the Area R excavation
- Approximately 12,892 m^3 available for slag backfill in the Area Q excavation
- Approximately 10,113 m^3 available for slag backfill in the Area V excavation
- Approximately 23,128 m^3 available for slag backfill in the Area K excavation

Following the reuse of the estimated 39,426 m^3 of slag, it is anticipated that Area K could accommodate an additional 12,144 m^3 of slag, should more be identified during the consolidation activities.

SEC-2 will be applied to Areas R, Q, and V and SEC-3 will be applied to Area K. As mentioned, the slag backfill will be covered with a geotextile filter to prevent the migration of fines into the slag. The simple earth (clay) cap designs (SEC-1 through SEC-4) also minimize the risk of mammals burrowing into the underlying wastes and have a thickness of 1.5 m, as required by the draft SLERA.

Simple Earth (Clay) Cap Placement. The area of the simple earth (clay) caps to be applied in the South Industrial Areas G, H, I, K, and M is approximately 49,623 m^2 and approximately 59,775 m^2 in the North Industrial Areas N, O, Q, R, T, and V. Figure 3-6 identifies the extent of the simple earth (clay) caps.

During placement, simple earth (clay) caps will be compacted in 30-cm lifts to 95 percent SPMDD under near optimum moisture contents. Laboratory compaction and permeability tests on the selected clay or low permeability material can be conducted to determine whether 95 percent SPMDD is sufficient to achieve desired permeability rates (10^{-7} cm/s) or whether the percentage of SPMDD will need to be greater than 95 percent.

Following the consolidation of HLW from the North Industrial Area, excavations containing underlying MLS will be backfilled with either slag or "clean" backfill and the 65-cm topsoil/clay cap. The placement of the simple earth (clay) cap will progress in order from Area N to Areas O, R, Q, V then T. Prior to placing the simple earth (clay) cap over Area N, a 45-cm diameter culvert extension will be installed in New Westerly Creek north of the main entrance to the mine site. The culvert will extend approximately 500 m to the Mine Area at the northern limit of the Industrial Area and will contain several access points for cleaning out the culvert. The culvert will be backfilled with "clean" imported sand prior to placement of the simple earth (clay) cap.

The placement of the simple earth (clay) cap in the South Industrial Area will progress in order from Area K to Areas M, G, I, then H. Existing pumping stations and above-ground piping may need to be altered to accommodate the new simple earth (clay) cap grade. Final design modelling will better determine the extent of these alterations to the existing groundwater collection system.

As previously mentioned, should Areas N, Q, T and G be used as an extension to the WCA, then the simple earth (clay) cap will not be applied in these areas.

The detailed schedule of simple earth (clay) cap placement is provided in Section 4.4.

Cross-sections through the post-consolidation Industrial Area and equalization pond are provided in Figures 3-10 to 3-12.

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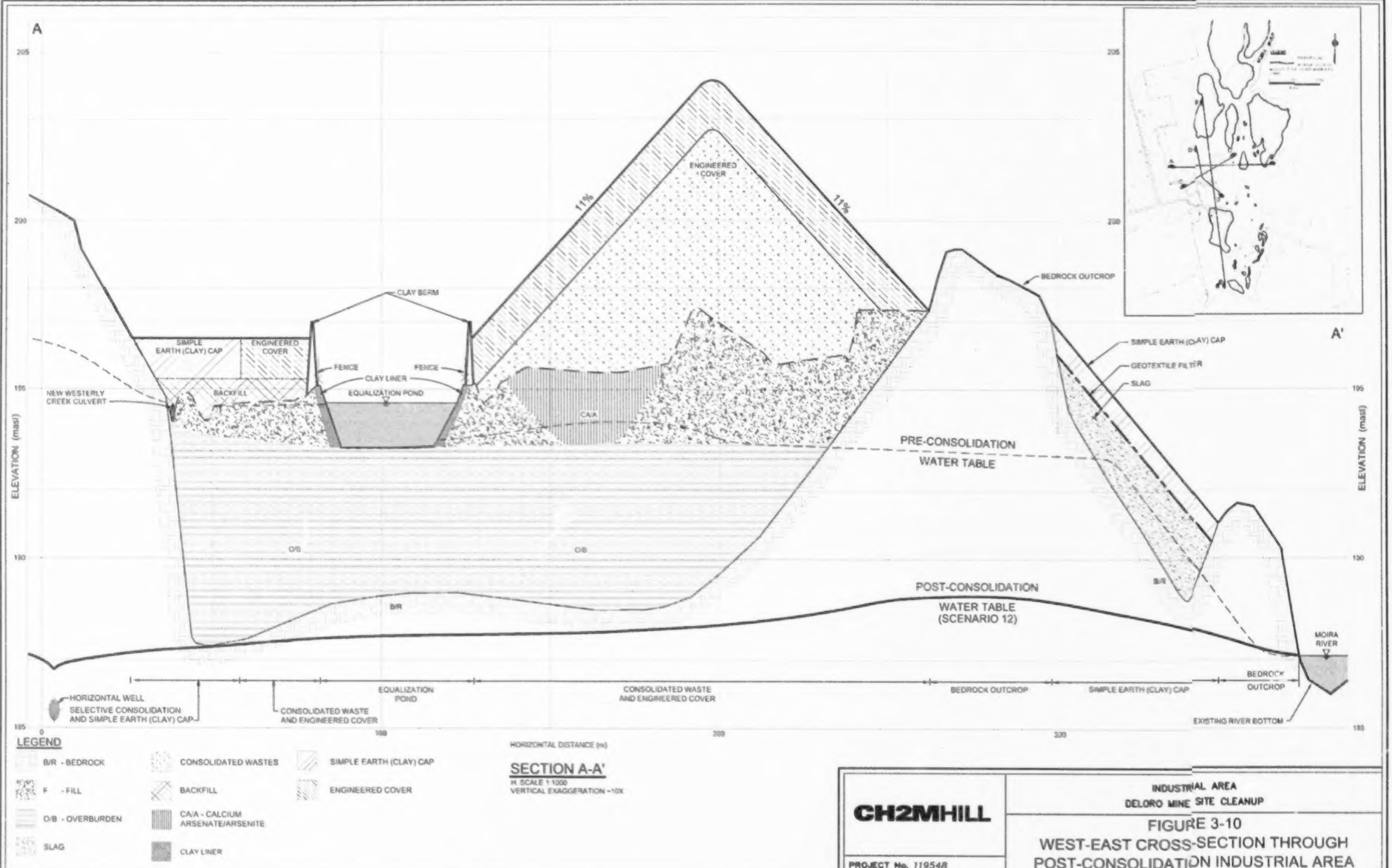
A
A'
205
200
195
190
185
ELEVATION (masl)
11%
11%
ENGINEERED COVER
CLAY BERM
SIMPLE EARTH (CLAY) CAP
ENGINEERED COVER
BACKFILL
FENCE
FENCE
CLAY LINER
EQUALIZATION POND
NEW WESTERLY CREEK CULVERT
CA/A
PRE-CONSOLIDATION WATER TABLE
O/B
O/B
B/R
B/R
POST-CONSOLIDATION WATER TABLE (SCENARIO 12)
BEDROCK OUTCROP
SIMPLE EARTH (CLAY) CAP
GEOTEXTILE FILTER
SLAG
MOIRA RIVER
HORIZONTAL WELL
SELECTIVE CONSOLIDATION AND SIMPLE EARTH (CLAY) CAP
CONSOLIDATED WASTE AND ENGINEERED COVER
EQUALIZATION POND
CONSOLIDATED WASTE AND ENGINEERED COVER
BEDROCK OUTCROP
SIMPLE EARTH (CLAY) CAP
BEDROCK OUTCROP
EXISTING RIVER BOTTOM
0
100
200
300
HORIZONTAL DISTANCE (m)
LEGEND
B/R - BEDROCK
F - FILL
O/B - OVERBURDEN
SLAG
CONSOLIDATED WASTES
BACKFILL
CA/A - CALCIUM ARSENATE/ARSENITE
CLAY LINER
SIMPLE EARTH (CLAY) CAP
ENGINEERED COVER

SECTION A-A'
H. SCALE 1:1000
VERTICAL EXAGGERATION ~10X

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INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

FIGURE 3-10
WEST-EAST CROSS-SECTION THROUGH
POST-CONSOLIDATION INDUSTRIAL AREA

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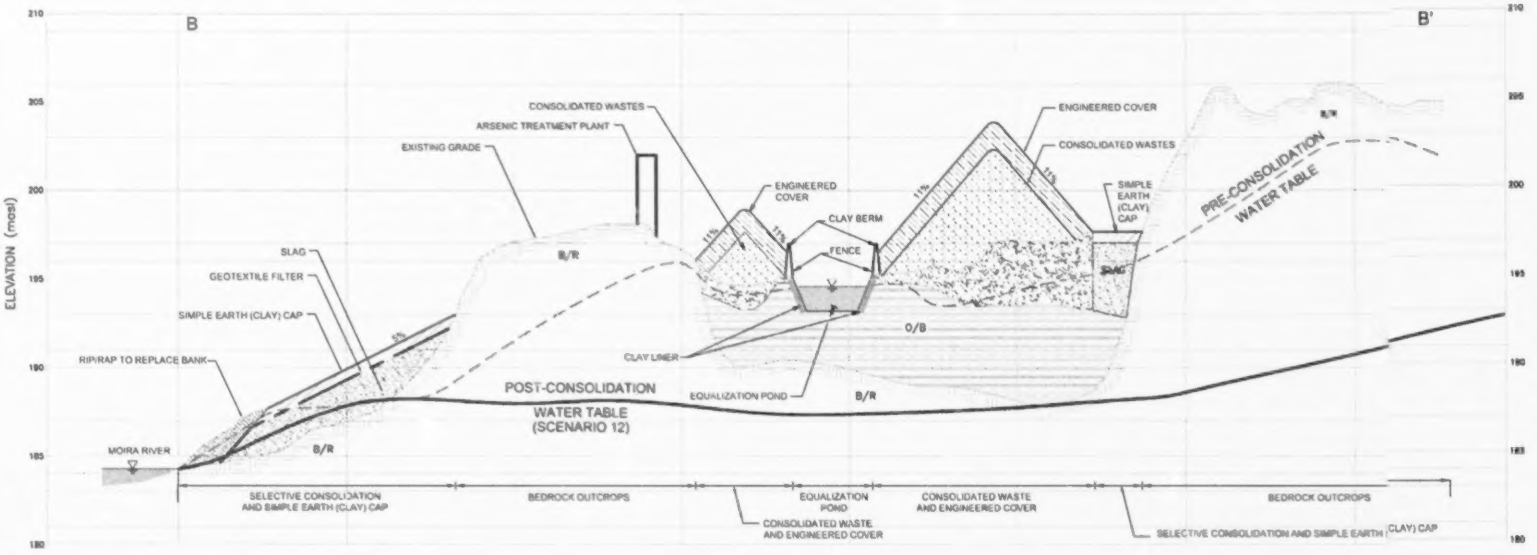
22/JULY/2004

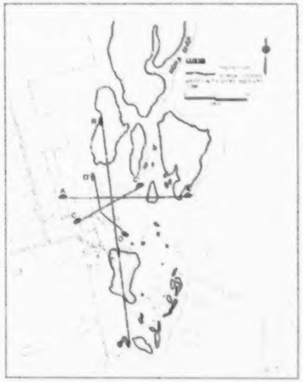


ELEVATION (masl)
210
205
200
195
190
185
180
B
B'
MOIRA RIVER
RIP/RAP TO REPLACE BANK
SIMPLE EARTH (CLAY) CAP
GEOTEXTILE FILTER
SLAG
EXISTING GRADE
ARSENIC TREATMENT PLANT
CONSOLIDATED WASTES
ENGINEERED COVER
CLAY BERM
FENCE
CLAY LINER
EQUALIZATION POND
ENGINEERED COVER
CONSOLIDATED WASTES
SIMPLE EARTH (CLAY) CAP
SLAG
PRE-CONSOLIDATION WATER TABLE
POST-CONSOLIDATION WATER TABLE (SCENARIO 12)
B/R
O/B
11%
5%
SELECTIVE CONSOLIDATION AND SIMPLE EARTH (CLAY) CAP
BEDROCK OUTCROPS
CONSOLIDATED WASTE AND ENGINEERED COVER
EQUALIZATION POND
CONSOLIDATED WASTE AND ENGINEERED COVER
SELECTIVE CONSOLIDATION AND SIMPLE EARTH (CLAY) CAP
BEDROCK OUTCROPS

HORIZONTAL DISTANCE (m)

SECTION B-B'

H. SCALE 1:2500
VERTICAL EXAGGERATION ~10X



LEGEND

▨	B/R - BEDROCK
▨	F - FILL
▤	O/B - OVERBURDEN
■	CLAY LINER
▨	CONSOLIDATED WASTES
▨	BACKFILL
▨	SLAG
▨	SIMPLE EARTH (CLAY) CAP
▨	ENGINEERED COVER
▨	RIP/RAP

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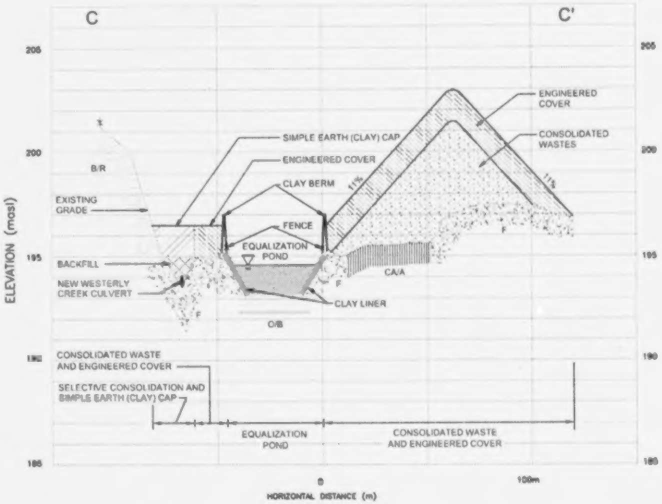
INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

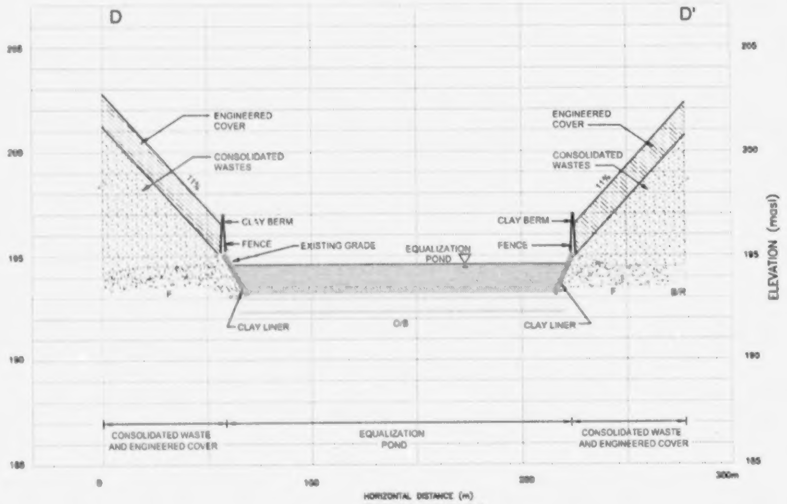
FIGURE 3-11
SOUTH-NORTH CROSS-SECTION THROUGH
POST-CONSOLIDATION INDUSTRIAL AREA

44246F20K


C
C'
205
200
195
190
185
ELEVATION (masl)
B/R
EXISTING GRADE
BACKFILL
NEW WESTERLY CREEK CULVERT
F
SIMPLE EARTH (CLAY) CAP
ENGINEERED COVER
CLAY BERM
FENCE
EQUALIZATION POND
CLAY LINER
O/B
CA/A
11%
ENGINEERED COVER
CONSOLIDATED WASTES
CONSOLIDATED WASTE AND ENGINEERED COVER
SELECTIVE CONSOLIDATION AND SIMPLE EARTH (CLAY) CAP
EQUALIZATION POND
CONSOLIDATED WASTE AND ENGINEERED COVER
0
100m
HORIZONTAL DISTANCE (m)

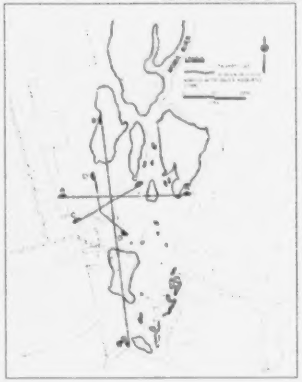
SECTION C-C'

H. SCALE 1:2000
VERTICAL EXAGGERATION ~10X


D
D'
205
200
195
190
185
ELEVATION (masl)
ENGINEERED COVER
CONSOLIDATED WASTES
11%
CLAY BERM
FENCE
EXISTING GRADE
EQUALIZATION POND
F
B/R
O/B
CLAY LINER
CONSOLIDATED WASTE AND ENGINEERED COVER
EQUALIZATION POND
0
100
200
300m
HORIZONTAL DISTANCE (m)

SECTION D-D'

H. SCALE 1:2000
VERTICAL EXAGGERATION ~10X



LEGEND

B/R - BEDROCK	
F - FILL	
O/B - OVERBURDEN	
▨	CONSOLIDATED WASTES
▨	BACKFILL
▥	CA/A - CALCIUM ARSENATE/ARSENITE
▨	SIMPLE EARTH (CLAY) CAP
▨	ENGINEERED COVER
■	CLAY LINER

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INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

FIGURE 3-12
EQUALIZATION POND CROSS-SECTIONS THROUGH
POST-CONSOLIDATION INDUSTRIAL AREA

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3.4.2 Plans and Profiles

The following plans and profiles have been discussed in Section 3:

- Figure 3-1: The location of structures to be demolished
- Figure 3-2: The subdivision of the Industrial Area into smaller, more manageable areas
- Figure 3-3: The approximate locations of low-level radiation fields at the site
- Figure 3-4: A west-east cross-section through the existing site conditions
- Figure 3-5: A south-north cross-section through the existing site conditions
- Figure 3-6: The extent of the WCA with engineered cover and the simple earth (clay) caps
- Figure 3-7: A profile of the engineered cover design
- Figure 3-8: Profiles of the various simple earth (clay) cap scenarios
- Figure 3-9: A profile of the engineered cover and simple earth (clay) cap interface with the main road into the site
- Figure 3-10: A west-east cross-section through the post-consolidation Industrial Area
- Figure 3-11: A south-north cross-section through the post-consolidation Industrial Area
- Figure 3-12: Post-consolidation cross-sections through the equalization pond

The following plans and profiles will be discussed in upcoming sections of the Closure Plan:

- Figure 3-13: The layout of the horizontal well, vertical pressure relief wells, and vertical shafts (i.e. GIWN)
- Figure 3-14: Existing groundwater collection and surface water sampling stations
- Figure 3-15: The current and anticipated future water flows to the ATP
- Figure 3-16: The existing site grading
- Figure 3-17: Typical cross-section of the riverbank reconstruction

3.4.3 Material Sourcing and Haulage Routes

Clay, sand, silty clay loam, topsoil, and other material sources are currently being identified and verified by CH2M HILL. This will be completed during the design phase, following acceptance of the Closure Plan.

Past inquiries have identified only a small supply of local clayey soils for the layers of the engineered cover and simple earth (clay) caps. Therefore, the design may vary slightly depending on the local availability of cover materials at the commencement of construction activities, and the cost of transporting imported cover materials from distant sources.

A benefit-cost analysis may be required to assist in the final design decision-making.

3.5 Water Management

Although the waste consolidation and cover remediation alternative is expected to significantly reduce contaminant loads to the Moira River, it is doubtful, in the absence of enhancing environmental protection features, that it alone will satisfy the interim PWQO (MOE, 1994) for dissolved arsenic concentration in the waters of the Moira River at the intersection of Highway 7, south of the Deloro Mine Site.

Consolidation of the wastes will reduce the surface area over which surface water infiltration may contact the wastes. This is expected to result in a significant decrease in the mass of dissolved contaminants that will reach the water table. Furthermore, the engineered cover and simple earth (clay) caps will also reduce surface water infiltration into the wastes, transportation of dissolved contaminants and fine particulates via surface runoff to the Moira River, and airborne transportation of particulates.

However, it has been established in previous studies that groundwater enters the western site boundary and flows eastward through bedrock, overburden and the wastes to the Moira River. Although a groundwater collection and treatment system is in use at the site, which reduces the volume of arsenic-impacted groundwater that reaches the Moira River, the system does not capture all of the arsenic-impacted groundwater.

A more effective way to control groundwater contaminant migration at the site is to minimize groundwater contact with the wastes by diverting groundwater flow away from the wastes. These enhancing features are described further in Section 3.5.2.

3.5.1 Industrial Area Water Balance

A water balance was developed for the north/central portion of the Industrial Area on the west bank of the Moira River containing the calcium arsenate/arsenite stockpile and the existing groundwater collection system.

The main components of the water balance are the inputs (precipitation, evapotranspiration, infiltration, groundwater inflow, run-on) and the outputs, which include naturally occurring discharges (runoff, Industrial Area and Mine Area groundwater in overburden and bedrock, Tuttle Shaft gravity flow) and water collection system discharges (Industrial Area groundwater collection system, Tuttle Shaft collection).

The water balance and loading study for the Deloro Mine Site on the West Bank of the Moira River (CH2M HILL, March 2002a) concluded that:

- 85 percent of the water input into the site is due to groundwater inflow from the west
- 42 percent of the water output from the site, west of the Moira River, is due to the groundwater collection system
- 36 percent of the water output from the Industrial Area is due to the groundwater collection system
- 34 percent of the water output from the site, west of the Moira River, is due to surface water runoff
- Surface water from the Industrial Area contributes 7 percent to 37 percent of the total arsenic loading from the site to the Moira River north of Highway 7, depending on arsenic concentrations in runoff
- 6 percent of the water output from the site is due to groundwater seepage
- Groundwater seepage from the Industrial Area contributes 69 percent of the total arsenic loading from the site to the Moira River north of Highway 7

As can be seen, mitigation of arsenic loading will require implementation of control measures for surface water and groundwater migration for several source areas in the Industrial Area. The management and control of surface water (seeps, creeks, streams, rivers), stormwater (rainfall, snowfall, snowmelt) and groundwater during and following construction activities at the site will be critical to the success of the Industrial Area rehabilitation, and the Deloro Mine Site Cleanup as a whole.

Items 7 and 8 in Section 1.6 identify the two key components associated with the management of groundwater in the Industrial Area, including:

- The GIWN - comprising a horizontal well and series of vertical pressure relief wells, installed west of the engineered cover, to lower the water table under the wastes to below the bedrock surface and to divert clean groundwater away from the wastes
- Leachate collection and treatment (including residue and sludge management) - continued operation of the existing ATP to reduce arsenic loadings to the Moira River and management of accumulated arsenic-laden residue and sludge

These two main components of groundwater management in the Industrial Area are discussed in further detail in Section 3.5.2.

3.5.2 Groundwater Management

Groundwater Geochemistry

The natural groundwater at the site seems to be relatively free of most metal species. However, background wells exhibit elevated levels of arsenic. Arsenic concentrations in the overburden groundwater have ranged from non-detect in the background well to 2,190 mg/L in the well immediately downgradient from the calcium arsenate/arsenite stockpile. With the exception of one well, arsenic concentrations have exceeded acceptable concentrations in all of the onsite wells at some point in the monitoring history.

In the bedrock, the arsenic concentration ranges from 0.05 mg/L in the deep bedrock at the extreme south end of the Industrial Area to 1,400 mg/L in the shallow bedrock east of the calcium arsenate/arsenite stockpile. A high spike of 2,100 mg/L was measured in October 1993 in the well immediately north (i.e. upgradient) of the concrete cut-off wall.

In addition to the elevated levels of arsenic in groundwater, many of the wells in the Industrial Area exhibit elevated levels of cobalt exceeding 100 µg/L, and other metal contaminants. Both arsenic and mercury are known to occur in the natural bedrock in the vicinity of the site.

Groundwater Inflow

Groundwater flows into and across the Industrial Area from west to east, originating primarily from a recharge area within the elevated limestone plateau beneath and to the west of the Village of Deloro. This flow occurs primarily through fractured bedrock and a permeable stratum of silty sand and gravel that overlies bedrock throughout much of the site. Hydraulic conditions lead to a water table rise into the waste materials in the vicinity of the calcium arsenate/arsenite stockpile.

Minimization of this groundwater inflow is critical to reducing the arsenic loading to the Moira River.

The elevation and depth of the existing water table are provided in Figures 3-4 and 3-5.

Groundwater Interceptor Well Network

As noted in Section 2.2.2, the results of the 2004 groundwater flow modelling indicated that Scenario 12 was effective at achieving the desired groundwater diversion/control and complete overburden dewatering in the Industrial Area. This scenario utilized a GIWN comprised of a horizontal well advanced into the bedrock on the west side of the site and a series of vertical pressure relief wells extending approximately 30 m into the bedrock. The vertical pressure relief wells would flow by artesian pressure and would be connected to, or be in close proximity of, the horizontal well. The intercepted groundwater would flow by gravity from the horizontal well, through a conveyance pipe, to the Moira River at the south end of the Industrial Area. As proposed, the GIWN would be a completely passive operation.

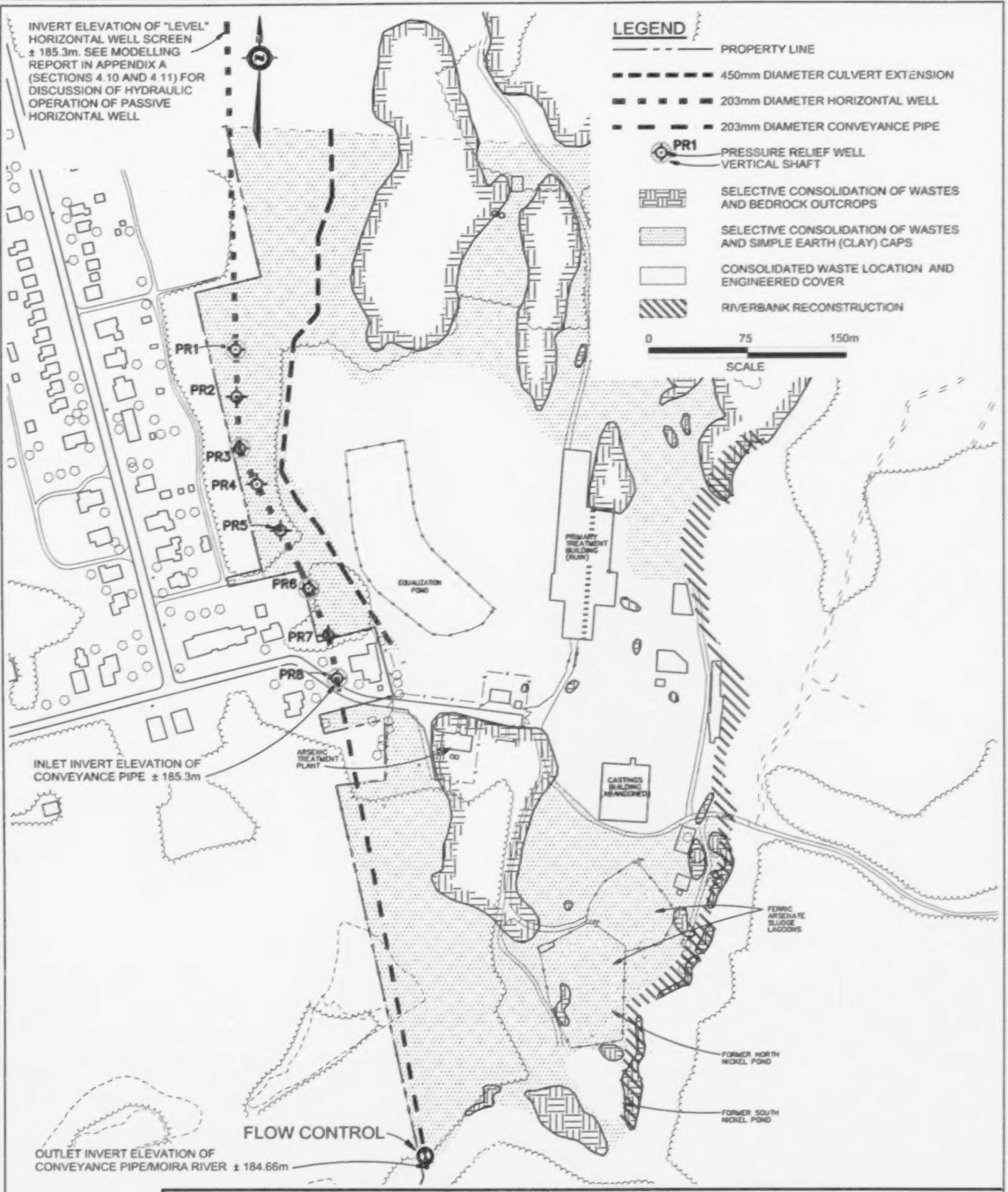
The GIWN would be designed and operated to minimize the potential for drawing contaminated groundwater from below the WCA into the horizontal and vertical wells, thereby minimizing requirements for treatment of the intercepted groundwater, if at all, to allow discharge of the water to the Moira River. As noted in Section 2.2.2, conservative contaminant transport modelling should be carried out to confirm the present analysis that the potential for contaminated groundwater to enter the horizontal and vertical wells, from under the engineered cover, is low. Currently, it is predicted that groundwater coming from the shallow bedrock under the engineered cover to the horizontal well and vertical wells will be diluted by a factor of approximately 12.9:1, when the entire flow into the system is considered.

Based on the modelling results, the proposed GIWN would lower groundwater levels beneath the WCA to below the bedrock surface, approximately three to four metres below the base of the calcium arsenate/arsenite wastes. This would reduce the potential for continued contaminant dissolution in groundwater through direct contact with the wastes and the migration of contaminated groundwater eastward towards the Moira River. The predicted groundwater levels following implementation of the GIWN are shown in Figures 3-10 and 3-11.

This scenario assumes that some of the existing groundwater pumping stations would continue to operate to capture contaminated groundwater from beneath the WCA (see Appendix A), at least until such time as groundwater capture and treatment is no longer required. Further details on leachate control are provided in Section 3.5.4.

It is anticipated that the GIWN would comprise:

- 500-m of screened, 203-mm diameter, stainless steel horizontal well placed several metres into the bedrock at a "level" elevation of 185.3 m along the west side of the WCA. While the horizontal well could be sloped, as previously noted, Figures 15 and 16 (Scenario 11) and Figures 18 and 19 (Scenario 12) in Appendix A show that the predicted hydraulic gradient along the horizontal well results in flow into the "level" horizontal well screen and flow from north to south along the horizontal well alignment.
- 373-m of 203-mm diameter, high density polyethylene (HDPE) piping (also advanced using horizontal drilling) to convey the water from the outlet of the horizontal well screen southward to the river. The inlet and outlet elevations (Figure 3-13) of this pipe were selected to accommodate the head loss in this gravity flow pipe.
- Eight 150-mm diameter polyvinyl chloride (PVC) pressure relief wells, extending approximately 30 m into bedrock and connected to the horizontal well to reduce the hydraulic head of the groundwater in the deep bedrock.


INVERT ELEVATION OF "LEVEL" HORIZONTAL WELL SCREEN ± 185.3m. SEE MODELLING REPORT IN APPENDIX A (SECTIONS 4.10 AND 4.11) FOR DISCUSSION OF HYDRAULIC OPERATION OF PASSIVE HORIZONTAL WELL
N
LEGEND
PROPERTY LINE
450mm DIAMETER CULVERT EXTENSION
203mm DIAMETER HORIZONTAL WELL
203mm DIAMETER CONVEYANCE PIPE
PR1
PRESSURE RELIEF WELL
VERTICAL SHAFT
SELECTIVE CONSOLIDATION OF WASTES AND BEDROCK OUTCROPS
SELECTIVE CONSOLIDATION OF WASTES AND SIMPLE EARTH (CLAY) CAPS
CONSOLIDATED WASTE LOCATION AND ENGINEERED COVER
RIVERBANK RECONSTRUCTION
0
75
150m
SCALE
PR1
PR2
PR3
PR4
PR5
PR6
PR7
PR8
EQUALIZATION POND
PRIMARY TREATMENT BUILDING (RUIN)
ARSENIC TREATMENT PLANT
CASTINGS BUILDING (ABANDONED)
FERRIC ARSENATE SLUDGE LAGOONS
FORMER NORTH NICKEL POND
FORMER SOUTH NICKEL POND
INLET INVERT ELEVATION OF CONVEYANCE PIPE ± 185.3m
FLOW CONTROL
OUTLET INVERT ELEVATION OF CONVEYANCE PIPE/MOIRA RIVER ± 184.66m

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DELORO MINE SITE CLEANUP

FIGURE 3-13
CONCEPTUAL LAYOUT OF HORIZONTAL GROUNDWATER INTERCEPTOR WELL NETWORK

- Four 3.7 m by 3.7 m vertical shafts, installed at four of the pressure relief wells, and extended into the overburden and bedrock to the underside of the horizontal well. These shafts would be designed to provide access to the horizontal and vertical wells at these locations to facilitate direct piping connections and for access for future flow control and monitoring, if desired. At the remaining four locations of the pressure relief wells, the system would rely on hydraulic connections between the wells through fractures in the bedrock. The hydraulic connections would be enhanced by hydraulic fracturing of the four vertical bedrock wells, to increase the hydraulic conductivity of the bedrock aquifer, thereby enhancing the flow of groundwater into the horizontal well under existing vertical hydraulic gradients.
- A groundwater flow control mechanism in the form of a valve or weir at the outlet of the conveyance pipe, as well as an accumulating flow meter.

A preliminary conceptual layout of the GIWN is shown in Figure 3-13 and the approximate depth of the horizontal well is shown in Figure 3-10. Verification of the layout, depths, and spacing of the horizontal and vertical pressure relief wells and the vertical shafts will need to be further assessed during future hydrogeological field investigations at the site (see Section 2.2) and additional groundwater flow modelling.

Groundwater Management during Excavations

Seepage of contaminated groundwater into excavations will likely occur during waste consolidation efforts in the Industrial Area. The inflow will be handled using conventional pumping techniques. In some areas, more aggressive water management techniques such as the use of well points or interceptor trenches may be required.

The potential for groundwater contamination exists; therefore, groundwater seepage and runoff into excavations will be collected and pumped to the existing equalization pond or a temporary retention pond for settling and treatment prior to discharge.

The coordination of treatment plant operations with the onsite construction will be required to ensure that sufficient water storage capacity is made available. This capacity may be achieved by:

- Lowering groundwater levels prior to construction
- Lowering water levels in the equalization pond prior to construction
- Reducing pumping from the collector system during construction
- Scheduling construction for the dry summer months

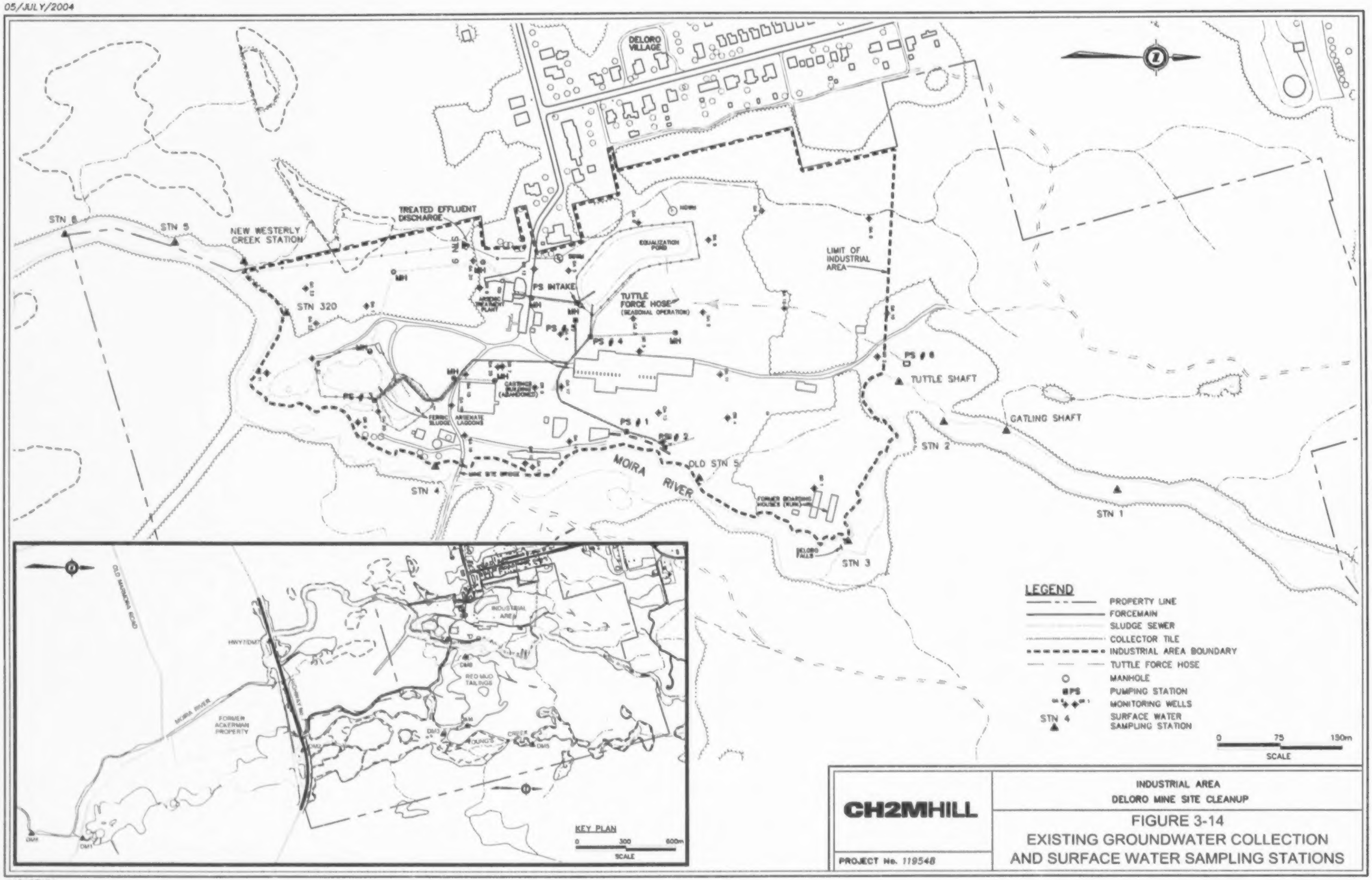
3.5.3 Surface Water and Stormwater Management

Surface Water Geochemistry

At surface water sampling stations along the Moira River, upstream and downstream of the Industrial Area, water is sampled and analyzed by OCWA for arsenic and other metals on a weekly basis. Average concentrations of arsenic in the Moira River adjacent to the site are generally below the acceptable limits, except during the late summer low river flows.

Arsenic concentrations in the Moira River have been known to increase to 40 times the background or upstream value as the water crosses the Industrial Area. The Moira River sampling stations are shown in Figure 3-14.

05/JULY/2004


DELORO VILLAGE
TREATED EFFLUENT DISCHARGE
STN 6
STN 5
NEW WESTERLY CREEK STATION
STN 9
STN 320
MH
ARSENIC TREATMENT PLANT
PS INTAKE
EQUALIZATION POND
TUTTLE FORCE HOSE (SEASONAL OPERATION)
PS # 5
PS # 4
PS # 3
CASTINGS BUILDINGS (ABANDONED)
FERRIC SLUDGE
ARSENATE LAGOONS
MINE SITE BRIDGE
STN 4
PS # 1
PS # 2
MOIRA RIVER
OLD STN 5
FORMER BOARDING HOUSES (RUIN)
DELORO FALLS
STN 3
LIMIT OF INDUSTRIAL AREA
PS # 6
TUTTLE SHAFT
GATLING SHAFT
STN 2
STN 1
LEGEND
PROPERTY LINE
FORCEMAIN
SLUDGE SEWER
COLLECTOR TILE
INDUSTRIAL AREA BOUNDARY
TUTTLE FORCE HOSE
MANHOLE
PS
PUMPING STATION
MONITORING WELLS
STN 4
SURFACE WATER SAMPLING STATION
0
75
150m
SCALE
OLD MARMORA ROAD
HWY7/DM7
MOIRA RIVER
FORMER ACKERMAN PROPERTY
HIGHWAY No. 7
INDUSTRIAL AREA
DM8
RED MUD TAILINGS
DM6
DM3
YOUNG'S CREEK
DM5
DM2
DM1
KEY PLAN
0
300
600m
SCALE

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INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

FIGURE 3-14
EXISTING GROUNDWATER COLLECTION AND SURFACE WATER SAMPLING STATIONS

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Runoff to the Moira River

The difference between precipitation and evapotranspiration is available for either infiltration to the ground below the root zone as recharge to groundwater, or as runoff to local surface watercourses. Using the estimated runoff coefficient of 28 percent, the central Industrial Area yields approximately 25,000 m^3 of annual runoff to the Moira River.

To minimize surface water and stormwater infiltration and erosion, appropriate runoff management controls must be implemented in the Industrial Area. Surface water drainage ditches will be the main component of surface water and stormwater management following the construction of the engineered cover and simple earth (clay) caps (see below).

Surface water protection is discussed in further detail in Section 4.7.3.

Runoff Management during Waste Consolidation

Surface water, snowmelt, and groundwater seepage will accumulate over the Industrial Area during the course of the waste consolidation activities. Runoff from newly exposed waste fill during the consolidation and grading of the site is a significant potential source of arsenic loading to the Moira River and abrupt increases in arsenic concentrations in the Moira River could occur during unprotected construction work. Effective collection and management of this water is important to minimize the discharge of water contaminated with arsenic and other contaminants into the Moira River.

Construction of a temporary clay berm along the west bank of the Moira River may be required to intercept surface water runoff and to direct this water to temporary impoundments, where pumping equipment can be installed to convey the runoff to the equalization pond for treatment via temporary overland pipes. During final capping of the site, the clay berm could be integrated into the engineered cover or simple earth (clay) caps.

Surface Water Drainage Ditches

Surface water drainage ditches will be constructed to prevent surface water runoff from reaching the engineered cover, thereby further minimizing infiltration through the cover. Surface water drainage ditches will be incorporated into the final grading design of the engineered cover and the simple earth (clay) caps. The surface water will drain by gravity to New Westerly Creek or to the Moira River.

Surface water drainage ditches may be initially routed into temporary retention/ sedimentation ponds, which could be used to collect stormwater during the waste consolidation activities. Water from the ponds would be pumped into the equalization pond, the Moira River or New Westerly Creek depending on the water quality.

Geotextile fabrics will be used to minimize erosion in surface water ditches.

3.5.4 Leachate Collection

The existing onsite groundwater collection system is designed to capture arsenic impacted groundwater before it reaches the Moira River. It consists of an ATP, an 80-m-long cut-off wall grouted into bedrock located at the western bank of the Moira River, a 9,084-m^3 equalization pond, and six pumping stations (PS#1 to PS#6). Figure 3-14 shows the layout of the existing groundwater collection system.

Pumping Stations

Pumping station #1 (PS#1), located at the south end of the concrete cut-off wall, collects water from two 150-mm perforated collector tiles and feeds the water via forcemain to the equalization pond.

Pumping station #2 (PS#2), located at the north end of the concrete cut-off wall, collects water from two 200-mm perforated collector tiles and feeds this water along the same forcemain as pumping station #1 to the equalization pond. The collector tiles are an average of 2.5 m below the existing grade, near the bedrock surface.

Pumping station #3 (PS#3), located at the south end of the north ferric arsenate sludge lagoon, extracts water from two 100-mm collector tiles that intercept the groundwater from the south end of the site. The tiles intercept the area from the pump to the northwest corner of the castings building. The collector line can be accessed at the north end via an inspection manhole. Four 100-mm sub-drains connected to the eastern tile, collect water draining from the sludge in the north ferric arsenate sludge lagoon. All of the water is transferred via a forcemain to the equalization pond.

Pumping station #4 (PS#4), located at the southeast corner of the calcium arsenate/arsenite stockpile, collects water from two 200-mm collector tiles. One tile spans the east side of the calcium arsenate/arsenite and the other spans the west between the calcium arsenate/arsenite and the equalization pond. The eastern tile can be accessed via an inspection manhole at the north end of the line. The water is routed via forcemain to the equalization pond.

Pumping station #5 (PS#5), located approximately 25 m southeast of the equalization pond, was installed to 8 m depth to intercept groundwater suspected to be influencing the water quality south of the ATP. The water is routed via forcemain to the equalization pond.

Pumping station #6 (PS#6) was installed to convey Tuttle Shaft seepage to the equalization pond via an aboveground discharge line. During low river flow periods in the summer months, groundwater seepage from the former Tuttle Shaft was found to have a measurable effect on the Moira River water quality. Presently, Tuttle Shaft pumping station is only operated during the summer months. Upgrades to the Tuttle Shaft groundwater pumping and conveyance system are detailed in the Mine Area Closure Plan (CH2M HILL, under development).

Equalization Pond

The existing groundwater collection and treatment system collects contaminated groundwater from a number of perforated subsurface collectors and conveys this water to the equalization pond in the northwest portion of the Industrial Area. The top of the berm elevation around the equalization pond is 195.2 masl, while the bottom of the equalization pond was constructed at elevation 193.2 masl. OCWA operates the site to maintain the equalization pond water level at elevation 194.6 masl. Golder Associates (Golder, March 1988) reports that the west central portion of the equalization pond is founded directly on fractured bedrock. However, one borehole advanced through the base of the equalization pond and 15 boreholes advanced adjacent, suggest that the base of the equalization pond is 2 to 3 m above bedrock. Eventual reduction of the size including rehabilitation of the equalization pond, if warranted on the basis of post-closure monitoring, is recommended to minimize the impact of infiltration from the equalization pond.

Figure 3-15 identifies the current volumes of water that are pumped to the equalization pond and the anticipated future flow rate to the pond following the implementation of the remedial measures. The anticipated reduction in future flows to the pond can primarily be attributed to the proposed GIWN, which will divert bedrock groundwater directly to the Moira River, effectively intercepting the groundwater that currently flows into the area of the calcium arsenate/arsenite wastes and reducing the flow rates from the existing pumping stations (see Appendix A). From the equalization pond, the water flows to a pumping station intake via a 200-mm-diameter underground pipe. The pumping station transfers the water via a 75-mm feed pipe to the ATP for treatment.

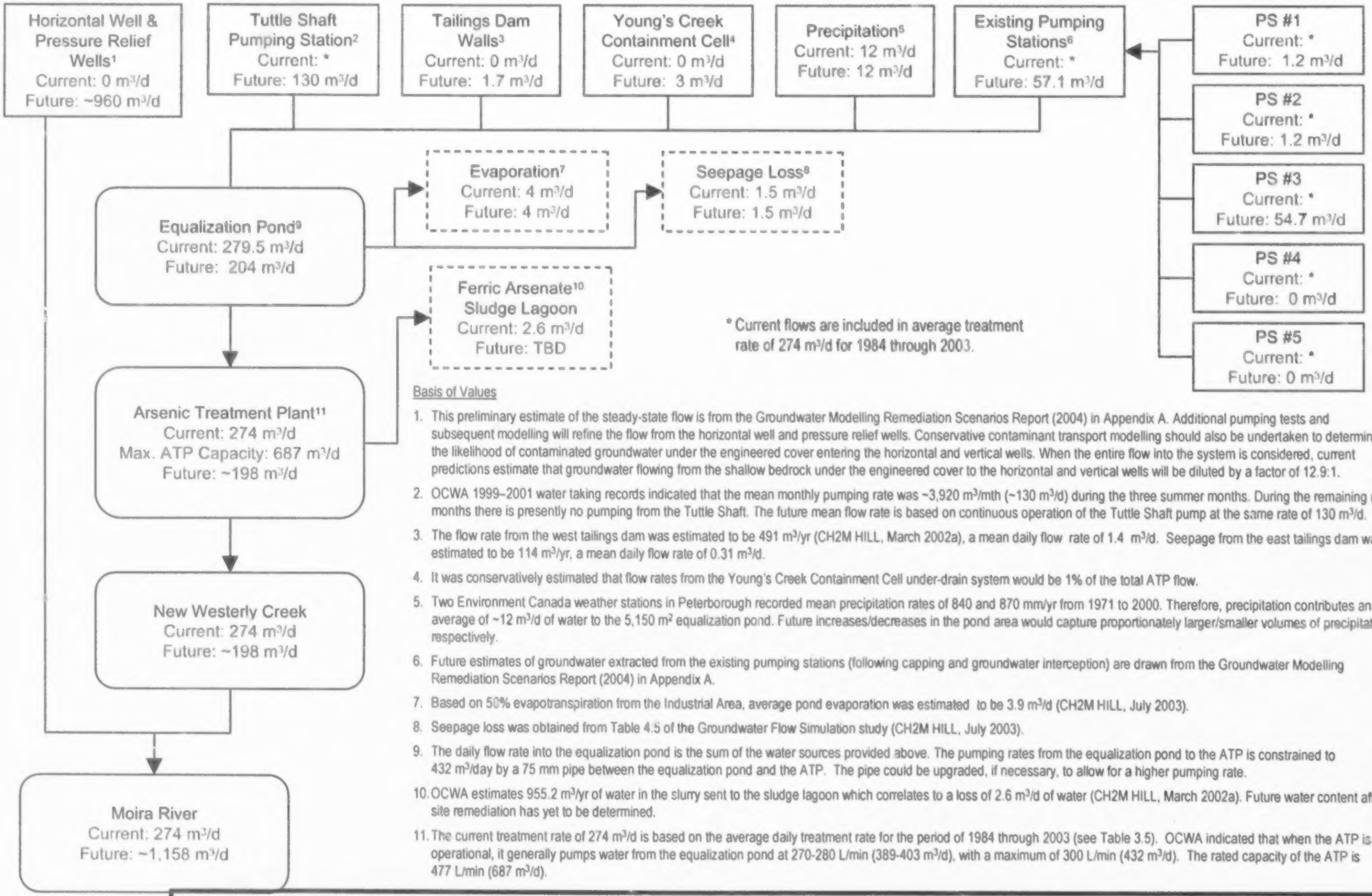
3.5.5 Leachate Treatment

The MOE has implemented various remediation strategies to reduce the arsenic loading to the Moira River since assuming control of the site in 1979. OCWA operates the ATP and groundwater collection system on behalf of the MOE. Annual average withdrawal rates of approximately 100,000 m^3/year have had a significant positive impact on Moira River water quality. The arsenic loading to the Moira River has been reduced by more than 80 percent to an annual average of less than 10 kg/day, since the ATP was placed into operation in 1983. Table 3.6 summarizes the ATP performance.

TABLE 3.6
DELORO ARSENIC TREATMENT PLANT PERFORMANCE

Year	Water Treated (m^3/yr)	Influent As (mg/L)	Effluent As (mg/L)	Treatment Efficiency (%)	Arsenic Removed (kg)
1984	82,295	189	0.361	99.8	17,787
1985	127,705	133	0.202	99.8	14,294
1986	168,422	89	0.223	99.7	13,561
1987	153,610	87.775	0.153	99.8	13,273
1988	164,341	99.334	0.127	99.9	15,729
1989	104,567	120.741	0.177	99.9	11,733
1990	99,842	110.071	0.194	99.8	10,913
1991	*	144.499	0.227	99.8	*
1992	87,139	161.714	0.199	99.9	12,734
1993	88,717	138.141	0.223	99.8	11,478
1994	169,868	105.313	0.187	99.8	16,380
1995	78,528	112.173	0.151	99.9	8,618
1996	86,525	147.696	0.164	99.9	12,738
1997	59,414	146.12	0.22	99.8	8,608
1998	65,099	127.50	0.27	99.8	8,346
1999	72,284	93.01	0.11	99.9	6,395
2000	71,439	125.43	0.19	99.9	8,905
2001	68,383	101.74	0.14	99.9	9,900
2002	72,010	116.23	0.17	99.8	8,542
2003	77,692	108.71	0.14	99.9	8,722
Average (excluding 1991)	99,888 m^3/yr (274 m^3/day)				

* Problem with Flow Meter
Source: OCWA, 1997a


Horizontal Well & Pressure Relief Wells¹
Current: 0 m³/d
Future: ~960 m³/d
Tuttle Shaft Pumping Station²
Current: *
Future: 130 m³/d
Tailings Dam Walls³
Current: 0 m³/d
Future: 1.7 m³/d
Young's Creek Containment Cell⁴
Current: 0 m³/d
Future: 3 m³/d
Precipitation⁵
Current: 12 m³/d
Future: 12 m³/d
Existing Pumping Stations⁶
Current: *
Future: 57.1 m³/d
PS #1
Current: *
Future: 1.2 m³/d
PS #2
Current: *
Future: 1.2 m³/d
PS #3
Current: *
Future: 54.7 m³/d
PS #4
Current: *
Future: 0 m³/d
PS #5
Current: *
Future: 0 m³/d
Equalization Pond⁹
Current: 279.5 m³/d
Future: 204 m³/d
Evaporation⁷
Current: 4 m³/d
Future: 4 m³/d
Seepage Loss⁸
Current: 1.5 m³/d
Future: 1.5 m³/d
Ferric Arsenate¹⁰ Sludge Lagoon
Current: 2.6 m³/d
Future: TBD
Arsenic Treatment Plant¹¹
Current: 274 m³/d
Max. ATP Capacity: 687 m³/d
Future: ~198 m³/d
New Westerly Creek
Current: 274 m³/d
Future: ~198 m³/d
Moira River
Current: 274 m³/d
Future: ~1,158 m³/d

* Current flows are included in average treatment rate of 274 m^3/d for 1984 through 2003.

Basis of Values

1. This preliminary estimate of the steady-state flow is from the Groundwater Modelling Remediation Scenarios Report (2004) in Appendix A. Additional pumping tests and subsequent modelling will refine the flow from the horizontal well and pressure relief wells. Conservative contaminant transport modelling should also be undertaken to determine the likelihood of contaminated groundwater under the engineered cover entering the horizontal and vertical wells. When the entire flow into the system is considered, current predictions estimate that groundwater flowing from the shallow bedrock under the engineered cover to the horizontal and vertical wells will be diluted by a factor of 12.9:1.
2. OCWA 1999–2001 water taking records indicated that the mean monthly pumping rate was ~3,920 m^3/mth (~130 m^3/d) during the three summer months. During the remaining nine months there is presently no pumping from the Tuttle Shaft. The future mean flow rate is based on continuous operation of the Tuttle Shaft pump at the same rate of 130 m^3/d.
3. The flow rate from the west tailings dam was estimated to be 491 m^3/yr (CH2M HILL, March 2002a), a mean daily flow rate of 1.4 m^3/d. Seepage from the east tailings dam was estimated to be 114 m^3/yr, a mean daily flow rate of 0.31 m^3/d.
4. It was conservatively estimated that flow rates from the Young's Creek Containment Cell under-drain system would be 1% of the total ATP flow.
5. Two Environment Canada weather stations in Peterborough recorded mean precipitation rates of 840 and 870 mm/yr from 1971 to 2000. Therefore, precipitation contributes an average of ~12 m^3/d of water to the 5,150 m^2 equalization pond. Future increases/decreases in the pond area would capture proportionately larger/smaller volumes of precipitation, respectively.
6. Future estimates of groundwater extracted from the existing pumping stations (following capping and groundwater interception) are drawn from the Groundwater Modelling Remediation Scenarios Report (2004) in Appendix A.
7. Based on 50% evapotranspiration from the Industrial Area, average pond evaporation was estimated to be 3.9 m^3/d (CH2M HILL, July 2003).
8. Seepage loss was obtained from Table 4.5 of the Groundwater Flow Simulation study (CH2M HILL, July 2003).
9. The daily flow rate into the equalization pond is the sum of the water sources provided above. The pumping rates from the equalization pond to the ATP is constrained to 432 m^3/day by a 75 mm pipe between the equalization pond and the ATP. The pipe could be upgraded, if necessary, to allow for a higher pumping rate.
10. OCWA estimates 955.2 m^3/yr of water in the slurry sent to the sludge lagoon which correlates to a loss of 2.6 m^3/d of water (CH2M HILL, March 2002a). Future water content after site remediation has yet to be determined.
11. The current treatment rate of 274 m^3/d is based on the average daily treatment rate for the period of 1984 through 2003 (see Table 3.5). OCWA indicated that when the ATP is operational, it generally pumps water from the equalization pond at 270-280 L/min (389-403 m^3/d), with a maximum of 300 L/min (432 m^3/d). The rated capacity of the ATP is 477 L/min (687 m^3/d).

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Figure 3-15
Current and Future Industrial Area
Water Flow Diagram

Similarly, the average annual arsenic concentrations in the Moira River decreased from 0.33 mg/L in 1979 to 0.03 mg/L in 1994, as measured at the Highway 7/Moira River monitoring station.

Collected groundwater enters the ATP from the equalization pond, passes through a flow meter and into a 2,135-L ferric chloride reactor. Within the reactor, the waters are mixed with ferric chloride for a nominal retention time of five minutes. The ferric chloride is pumped into the contact tank from one of two 23,000-L solution tanks to allow the arsenic time to react with the iron.

From the ferric chloride reactor, the waters flow into a 4,012-L lime reactor with a nominal retention time of 10 minutes. The waters are mixed with the lime slurry that is pumped into the tank from a 2,273-L mix tank. The slurry tank is fed from a 30-tonne hydrated lime storage silo and mixed with water from a 4,546-L makeup water storage tank. The makeup water can be either municipal water or plant effluent. The slurry is volumetrically fed to the lime reactor by a VFD (variable frequency drive) pump, which is electronically adjusted by a pH probe in the lime reactor. The lime raises the pH, which causes a ferric arsenate precipitate to form.

From the lime reactor, the water travels through a 200-mm line to a polymer reactor tank and mixes with a polymer solution to assist the formation of a ferric arsenate floc; the nominal retention time is five minutes. The polymer bags are placed into a dustless bag breaker and fed through a helix screw feeder into a wet box where the polymer dissolves in municipal water. The wet box discharges into the mix tank where the polymer is mixed and aged until it is needed.

Finally, the waters flow into a large 4.6-m diameter circular sludge clarifier. The ferric arsenate flocs settle out and form ferric arsenate sludge. One air compressor runs two pumps that feed the process sludge to the ferric arsenate sludge lagoon at the south end of the Industrial Area.

The ATP will receive increased flows from the proposed Tailings Area leachate collection system and the Tuttle Shaft, due to the planned increase to year-round pumping from several months of pumping per year, and from the proposed onsite containment cell in the Young's Creek Area. As indicated in Section 3.5.4, Figure 3-15 identifies the current volumes of water that are pumped to the ATP, and the anticipated future steady-state flow rates to the ATP following the implementation of the remedial measures. An anticipated overall reduction in average future flows to the ATP (from 274 m^3/d to approximately 198 m^3/d) can be mostly attributed to the proposed GIWN, which will reduce the flow rates from the existing pumping stations, more than offsetting the new flows. It is also anticipated that northern extension of the horizontal well may decrease the flow from the Tuttle Shaft (PS#6) although this potential reduction has not yet been quantified and is not shown in Figure 3-15. Additional modelling of the groundwater flow from the GIWN will be required, following completion of the proposed hydrogeologic field investigations, to better estimate the future flow rates to the ATP. It is also anticipated that contaminant concentrations will decrease with time as contaminated groundwater is removed from beneath the waste area and assuming that new leachate is not generated through direct contact of uncontaminated groundwater with the wastes.

It is anticipated that the existing groundwater collection and treatment system will continue in operation following completion of the planned rehabilitation program. Therefore, the decommissioning of the existing collection and treatment system is not specifically addressed as part of this Closure Plan.

3.5.6 Residue and Sludge Management

As discussed in Section 3.5.4, ferric arsenate sludge is produced on an ongoing basis from groundwater treatment operations at the site. This sludge is high in arsenic and is classified as a hazardous waste (leachate toxic) under O. Reg. 558. Estimates in 1997 (M. Newland, OCWA, 1997) indicate an annual sludge production of approximately 800 m^3. Sludge inventories are dewatered and disposed offsite at a hazardous waste landfill facility. CH2M HILL is further evaluating the sludge disposal options for the rehabilitated site.

The ferric arsenate sludge storage lagoon, which is based on a natural freeze/thaw dewatering design, is under-drained with a collection system. Excess water from the dewatering process drains by gravity to PS#3 and is returned to the equalization pond for treatment.

The effluent discharge is monitored by a pH probe, turbidity meter, and suspended solids meter. After treatment, the effluent water is pumped into the makeup tank or is allowed to outfall into New Westerly Creek. The sludge from the treatment process is pumped to the sludge storage lagoon through a 100-mm sludge sewer. The sludge sewer can be accessed at three points by inspection holes located approximately 60 m apart. During maintenance cycles, the outfall to the creek can be closed and a bypass is made to the equalization pond via a 150-mm pipe that passes through an inspection hole and widens to 200 mm.

Figure 3-14 shows the layout of the existing residue and sludge management features.

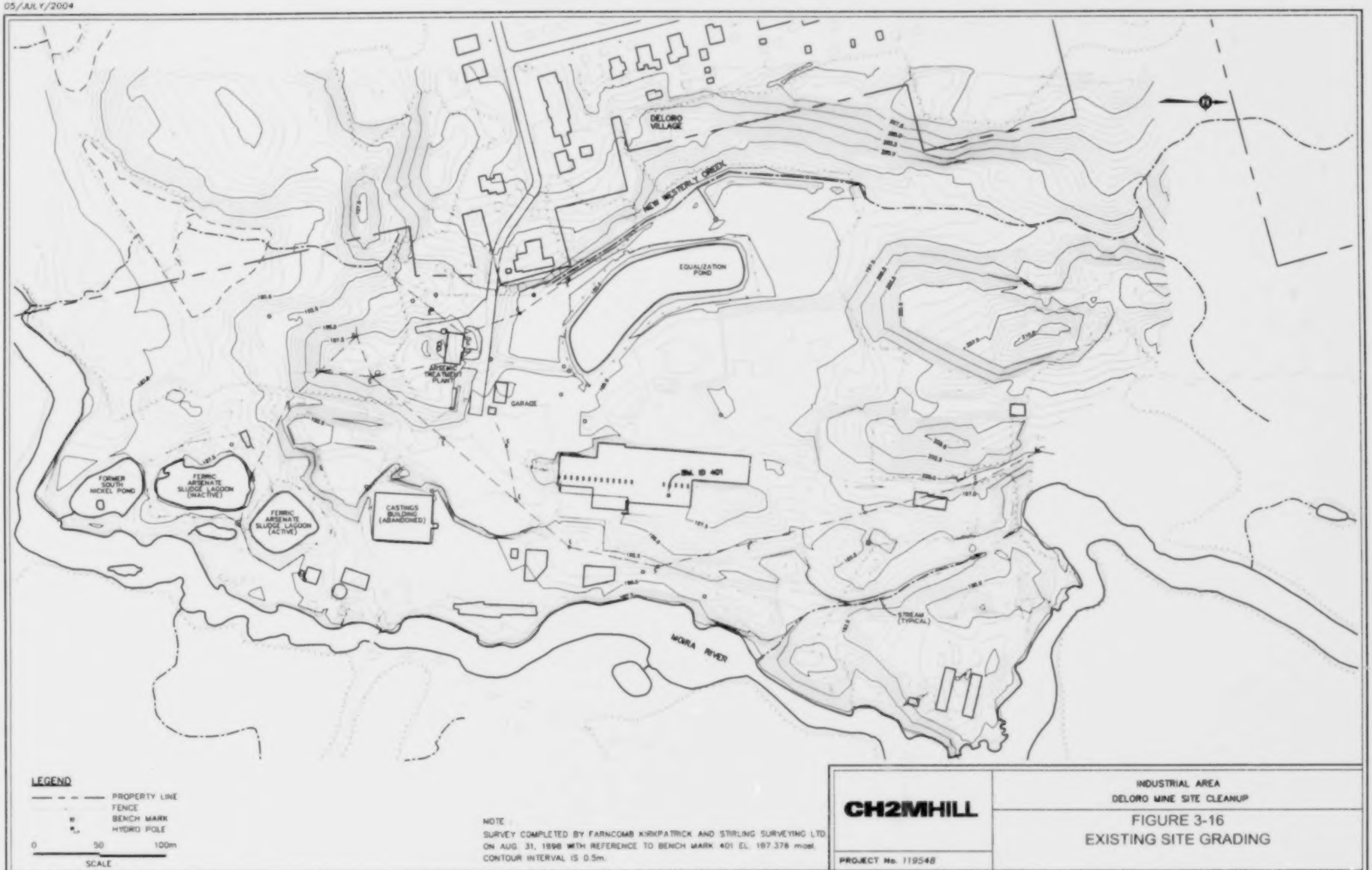
3.6 Mine Workings, Crown Pillars, and Surface Workings

During extensive studies within the Industrial Area, the MOE did not identify any crown pillars, surface workings, or mine workings. Details regarding the Closure Plans and a summary of mine closure activities can be found in the J.D.C. Dupont report entitled *Deloro Mine Workings Closure Plan* (January 1994) and the J.G. Ritter report entitled *Deloro Mine Site Rehabilitation, Summary Report on Mine Closure Activities* (October 1995), respectively.

3.7 Final Site Grading

The relative amount of precipitation available as infiltration to the ground below the root zone as recharge to groundwater is largely influenced by the topography and permeability of the ground surface cover. The average infiltration rate for the relatively flat, unvegetated, coarse textured soils of the central Industrial Area is significantly higher than the value for the global site balance. The topography of the existing site grade is shown in Figure 3-16.

05/JULY/2004


DELORO VILLAGE
NEW WESTERLY CREEK
EQUALIZATION POND
ARSENIC TREATMENT PLANT
GARAGE
BM. ID 401
FORMER SOUTH NICKEL POND
FERRIC ARSENATE SLUDGE LAGOON (INACTIVE)
FERRIC ARSENATE SLUDGE LAGOON (ACTIVE)
CASTINGS BUILDING (ABANDONED)
MOIRA RIVER
STREAM (TYPICAL)
LEGEND
PROPERTY LINE
FENCE
BENCH MARK
HYDRO POLE
0
50
100m
SCALE

NOTE :
SURVEY COMPLETED BY FARNCOMB KIRKPATRICK AND STIRLING SURVEYING LTD
ON AUG. 31, 1998 WITH REFERENCE TO BENCH MARK 401 EL. 187.378 masl.
CONTOUR INTERVAL IS 0.5m.

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INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

FIGURE 3-16
EXISTING SITE GRADING

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Extensive grading operations will be carried out prior to and during covering and capping of waste soils in the Industrial Area. The grading operations, which are to be conducted in concert with the consolidation of wastes, are intended to improve surface water drainage from the completed engineered cover/cap and ensure the long-term stability of the engineered cover/cap structure against natural erosion processes.

It is anticipated that the ground surface of the consolidated wastes and engineered cover will rise to a maximum elevation of approximately 205 masl; the approximate grade of the Village of Deloro. The mound will be approximately 5 m below the localized topographic high points at the north end of the Industrial Area. Tree cover between the Village and the WCA will reduce visual impacts to Deloro residents.

A 7.5 percent grade would likely be the optimum compromise between drainage and erosion resistance; however, space for waste consolidation is limited. Therefore, higher grades up to 11 percent may be necessary to accommodate the wastes. The grading plan for the site will include provision for drainage swales to convey surface water runoff away from waste areas and the equalization pond.

3.8 Site Rehabilitation and Revegetation

The completed engineered cover will be vegetated with both poplar trees and grass. The grass cover is intended for short-term erosion control until the tree cover is well established. Grass will eventually be shaded out as the canopy of the plantation reaches crown closure. With maturity, the trees' thick root system holds the soil together and the canopy of leaves shields the ground from raindrop impacts and consequent erosion. When the leaves fall in the autumn, they contribute to the mulch at the site and the overall water-holding capacity of the system. With time, the cover becomes a mature forest with little wind or water erosion.

The completed simple earth (clay) caps (SEC-1 to SEC-3) will be grassed only, as the topsoil layer provides for a shallow rooting structure that will not adequately support trees.

3.8.1 Riverbank and Water Courses

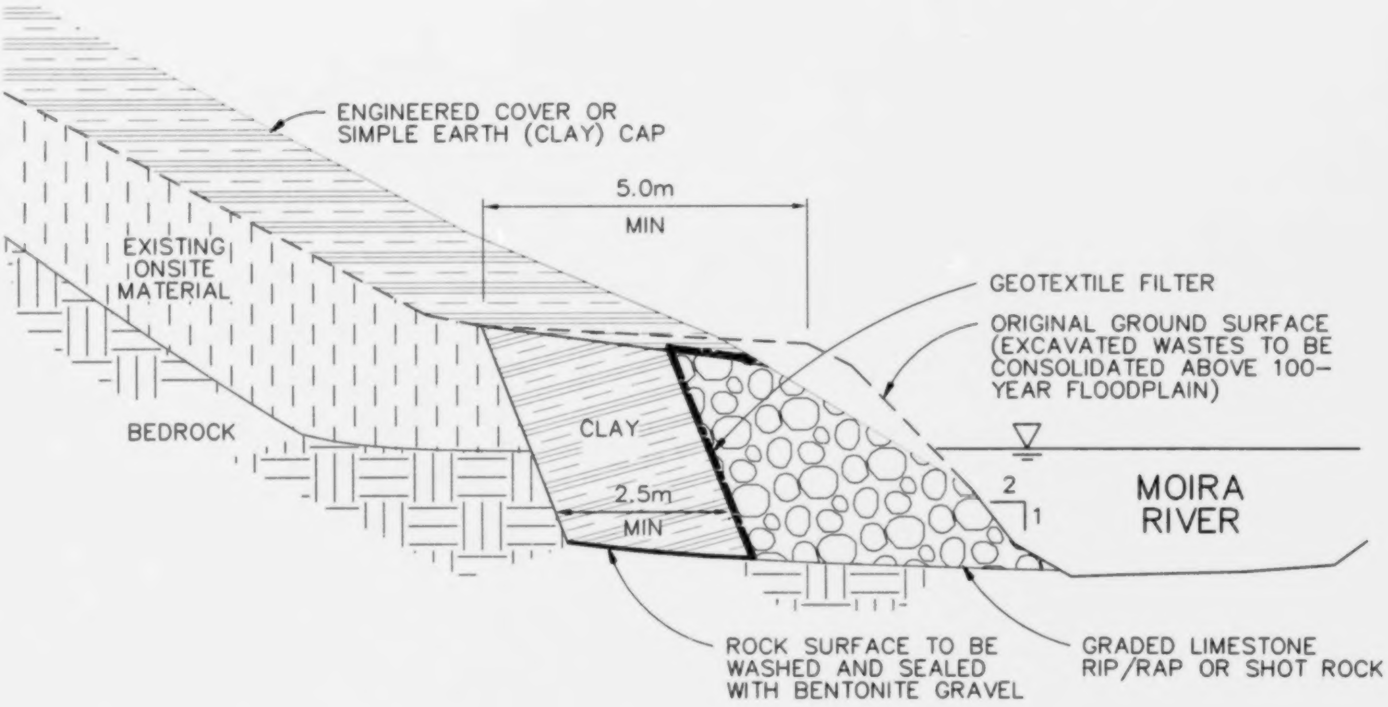
Another significant component of the remediation plan for the Industrial Area is the reconstruction of approximately 620 m of the west bank of the Moira River, where contaminated material is to be removed as noted in the report entitled *Deloro Mine Rehabilitation Project – Riverbank Reconstruction Alternatives for the Industrial Area, Final Report* (CH2M HILL, March 2002b). The riverbank to be reconstructed is identified as Area Z in Figure 3-2 and is also shown in Figure 3-6 relative to the engineered cover and simple earth (clay) caps. A cross-section of the reconstructed riverbank is provided in Figure 3-17.

Existing Riverbank Conditions

The 620-m section is bounded by a bedrock outcrop at both ends allowing for a clear start and end point to the reconstruction of the riverbank. The existing bank slopes vary from fairly gentle slopes at approximately 3:1 to steep slopes at 1:1 or near vertical.

In the most northern portion of the proposed reconstruction area, there is an underground concrete cut-off wall with groundwater collection pumps (PS#1 and PS#2) that convey arsenic-bearing groundwater through the water collection system.

22/JULY/2004


ENGINEERED COVER OR SIMPLE EARTH (CLAY) CAP
5.0m
MIN
EXISTING ONSITE MATERIAL
BEDROCK
CLAY
2.5m
MIN
GEOTEXTILE FILTER
ORIGINAL GROUND SURFACE (EXCAVATED WASTES TO BE CONSOLIDATED ABOVE 100-YEAR FLOODPLAIN)
2
1
MOIRA RIVER
ROCK SURFACE TO BE WASHED AND SEALED WITH BENTONITE GRAVEL
GRADED LIMESTONE RIP/RAP OR SHOT ROCK

NOT TO SCALE

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PROJECT No. 119548

INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

FIGURE 3-17
RIVERBANK RECONSTRUCTION
TYPICAL CROSS-SECTION

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The overburden stratigraphy, assessed from boreholes located along the riverbank, consists mainly of an upper layer of slag or brick fill underlain by a silty clay or sandy silt. In borehole GA15, adjacent to the west bank in the central part of the Industrial Area, a material suspected of being calcium arsenate was observed from 1.3-m below grade to bedrock at 2.8 m. The bank material at the toe of the slope consists mainly of local cobble and stone in a range of sizes that provide adequate erosion protection.

The vegetation along the west bank is sparse and discontinuous along the entire length of the proposed reconstruction. The vegetation is mainly composed of goldenrod, which is common in the surrounding area. Other common weeds are sparsely located along the bank. The vegetation is stressed from the poor growing conditions. The upper bank along the section of the river designated for reconstruction is, for the most part, lightly vegetated with local grasses and shrubs, which provide additional erosion protection to the top of the bank during flood flows.

The habitat character in the area of proposed riverbank reconstruction generally contains sparse riparian cover, but has extensive in-stream cover consisting of boulder and cobble substrates at riffle areas downstream of the mine site bridge crossing, and deep pools and a small embayment upstream of the mine site bridge crossing.

While there is productive in-stream fish habitat in the Moira River adjacent sections of proposed riverbank reconstruction, the history of past industrial disturbance and ongoing contaminant impacts to the Moira River have diminished the quality of the riparian and in-stream aquatic habitat. The potential long-term benefits of the rehabilitation program to minimize or eliminate all impacts and improve the site through cleanup, restoration and enhancement measures should provide a net positive enhancement to the productive capacity of fish habitat.

Excavation of Contaminated Materials

The streambank reconstruction methods will maintain the configuration of the stream as closely as possible to existing conditions of bank height, bank slope, and available floodplain. There is approximately 10,800 m^3 of waste soil that will be excavated from the riverbank and consolidated. The contaminated material comprising the existing bank will be removed, using standard techniques to minimize sediment suspension and transport. It will be stored onsite in Area B, graded, covered with a 50-cm clay layer and eventually covered with the entire treed engineered cover. Material will be removed to a minimum of 5 m distance from the existing riverbank. Removal of this material will provide for adequate contaminant removal and allow subsequent bank reconstruction. This will ensure the stability of the reconstructed bank and the protection of the compacted clay berm adjacent to the contaminated waste material, which will be left in place (CH2M HILL, March 2002b).

River Diversion

During the construction period, the Deloro dam or other flow diversion measures will be used to reduce the flow in the river to a level that will expose all bank materials slated for removal. If required, additional diversion capabilities to reduce flow volume may include pumping water from immediately below the falls to downstream of the construction area.

Streambed Protection, Erosion, and Sediment Controls

Consideration will be given to construction methods that minimize the impact on the existing streambed. No heavy equipment will work in or use the streambed for access during construction. Sediment and erosion protection procedures will be undertaken during all phases of the construction to ensure adequate protection of the stream habitat. Measures will be implemented to prevent sediment material from entering the stream or being deposited in the streambed during the actual material removal process. Erosion protection will be provided on the construction site to prevent significant runoff of sediment material during construction. This erosion protection will consist of silt curtains and straw bale dams. Details of the onsite erosion protection plan will be documented in the contract specifications prior to construction.

Preliminary Reconstruction Design

The basic reconstruction of the streambank will be carried out using a rip/rap design. The rip/rap, which will be used to construct the streambank, will be comprised of local quarried shotrock or local graded limestone material with an average diameter of 200 cm or greater. The range of acceptable stone size for the reconstruction bank material will be a minimum diameter of 150 cm, to a maximum diameter of 250 cm. The average diameter for the rip/rap stone was selected based on erosion protection required for the mean stream velocity occurring during the 100-year storm event of approximately three meters per second.

This recommended primary cover layer of rip/rap stone will be set on a maximum of a 2:1 slope with a minimum thickness of 1 m, selected as a measure of protection for the compacted clay berm. The actual thickness of the primary cover layer of rip/rap will in most instances exceed the minimum thickness of 1 m due to the amount of contaminated material to be removed and subsequently required to be replaced to maintain the contours of the pre-existing streambank.

The 2:1 slope will be maintained, at a minimum, until the bank full height elevation is reached. Where possible, the surveyed elevation of the original streambank should be used to determine the appropriate elevation of the reconstructed top of the bank. The minimum elevation of the primary 2:1 rip/rap cover layer at the streambank, which corresponds approximately with the bank full height, is 190.0 masl.

3.8.2 Waste Removal Areas

Waste removal areas were discussed in Section 3.4.1.

3.8.3 Waste Isolation Areas

Waste isolation areas were discussed in Section 3.4.1.

3.8.4 Bedrock Outcrops

Bedrock outcrops were discussed in Section 3.4.1.

3.8.5 Temporary Works

Temporary works associated with the Industrial Area rehabilitation construction process may include:

- Temporary haul road construction to access areas that are currently inaccessible, which may require excavation, filling, and/or grading
- Dust controls for roads that will be used by haul trucks and other construction equipment
- Dam and/or diversion measures for watercourses to facilitate reconstruction of the west riverbank
- Silt fencing along the edge of watercourses
- Personal protective Equipment (PPE) decontamination and change facilities
- Decontamination/control stations
- Washpad for equipment and trucks
- Truck tarping stations
- Equipment laydown areas
- Equipment storage containers
- Office trailers

4. Implementation Plan

This section identifies the Industrial Area rehabilitation program work packages, presents a probable schedule and a cost opinion to complete the rehabilitation program. Anticipated construction impacts and mitigation measures are identified, as well as health hazards and the details of an Environmental and Community Health Protection Plan (ECHPP).

4.1 Identification of Work Packages

The work packages identified for the Industrial Area rehabilitation program are listed in Table 4.1.

TABLE 4.1
IDENTIFICATION OF INDUSTRIAL AREA WORK PACKAGES

Package ID	Industrial Area Work Package Description
IA-WP#1	Site Preparation
IA-WP#2	Demolition of Buildings/Tanks and Resizing/Consolidation of Ruins
IA-WP#3	Riverbank Reconstruction
IA-WP#4	Consolidation of Wastes
IA-WP#5	Simple Earth (Clay) Cap Placement
IA-WP#6	Engineered Cover Placement
IA-WP#7	Groundwater Interceptor Well Network
IA-WP#8	Site Revegetation
IA-OMM#1	Operation, Maintenance, and Monitoring (OMM)

In Section 4.2, the work packages have been subdivided into tasks and subtasks and reorganized for ease of implementation. The order of the tasks and subtasks is provided in Section 4.4.

4.2 Sequencing of Work Packages

Closure of the Industrial Area is best accomplished in stages that focus on minimizing impacts to the environment while completing the project in an efficient and logical manner. Construction activities are subdivided into a five-year work program with an operation, maintenance, and monitoring (OMM) program that extends into the foreseeable future. The sequencing of the work package tasks by year of implementation is listed in Table 4.2 below. In general, the work packages would be completed in the order listed in Table 4.2; however, the opportunity exists for some of the work packages and their subtasks to be completed concurrently to expedite the work program or to extend the work program to meet annual budget constraints. The schedule in Section 4.4 identifies the complete breakdown of each work package, including tasks and subtasks.

TABLE 4.2
YEARLY SEQUENCE OF INDUSTRIAL AREA WORK PACKAGE TASKS

Task ID	Tasks Description	Details
Year 1 – Site Preparation and Demolition		
IA-WP#1.1	Site Preparation	Site setup, construct decontamination pad, and site access routes
IA-WP#2.1	Demolition of Buildings and Tanks	Demolish existing buildings and tanks
IA-WP#2.2	Resizing and Consolidation of Ruins	Consolidate ruins
Year 2 – Riverbank Reconstruction		
IA-WP#1.2	Site Preparation	Site setup, grub trees/vegetation in cover and riverbank areas, decommission well adjacent to riverbank and wells in Year 2 cover areas
IA-WP#6.1	Clay Berm Around Perimeter of Equalization Pond	Construct a clay berm around the equalization pond
IA-WP#3	Riverbank Reconstruction	Excavate and consolidate riverbank wastes, reconstruct riverbank, and transfer slag from Area Z to G
IA-WP#6.2	Clay Cover over Riverbank Wastes	Place the initial lower clay layer to limit exposure to consolidated wastes until the engineered cover is fully completed
Year 3 – North Industrial Area Rehabilitation		
IA-WP#1.3	Site Preparation	Site setup, grub trees/vegetation in cover and North Industrial Areas, decommission wells in North Industrial Area and Year 3 cover areas, install New Westerly Creek 500 m culvert extension to Mine Area
IA-WP#4.1	Consolidation of North Industrial Area Wastes	Consolidate wastes from Areas N, O, P, R, Q, S, Y, X, W, U, V, and T. Transfer slag from Areas H and M to R, Areas M, E, and I to Q, and Areas I and G to V
IA-WP#6.3	Clay Cover over North Industrial Area Wastes	Cover Areas D, C, B and the north half of Areas F and E
IA-WP#5.1	Simple Earth (Clay) Cap Placement in North Industrial Area	Place a simple earth (clay) cap over Areas N, O, R, Q, V, and T
Year 4 – South Industrial Area Rehabilitation		
IA-WP#1.4	Site Preparation	Site setup, grub trees/vegetation in cover and South Industrial Areas, decommission wells in South Industrial Area and Year 4 cover areas
IA-WP#4.2	Consolidation of South Industrial Area Wastes	Consolidate wastes from Areas K, J, L, M, G, I, and H. Transfer slag from Area G to K
IA-WP#6.4	Clay Cover over South Industrial Area Wastes	Cover the south half of Areas E and F
IA-WP#6.5	Placement of Remaining Layers of Engineered Cover	Place the GCL over the initial clay layer, then complete the engineered cover with 25 cm of sand, 30 cm of clay, 35 cm of silty clay loam and 15 cm of silty loam topsoil
IA-WP#5.2	Simple Earth (Clay) Cap Placement in South Industrial Area	Place a simple earth (clay) cap over Areas K, M, G, I, and H
Year 5 – Groundwater Interceptor Well Network and Revegetation		
IA-WP#7	Groundwater Interceptor Well Network	Install a 500-m horizontal well screen, eight vertical pressure relief wells and 360 m water conveyance pipe
IA-WP#8	Site Revegetation	Revegetate the Industrial Area with grasses and shrubs, and poplar trees in the engineered cover
Annual – Site Operation, Maintenance, and Monitoring		
IA-OMM#1	OMM	Existing and future OMM of the ATP, groundwater collection system, simple earth (clay) caps, engineered cover, riverbank, and groundwater interceptor well network

4.3 Anticipated Construction Impacts and Mitigation Measures

Table 4.3 identifies the main anticipated construction impacts and potential mitigation measures to minimize the effect of these impacts.

TABLE 4.3
ANTICIPATED CONSTRUCTION IMPACTS AND MITIGATIVE MEASURES

Construction Impacts	Mitigation Measures
Clearing and grubbing of trees and shrubs during site preparation	Altered areas should be revegetated with native species. If possible, minimize cutting trees larger than 100 mm diameter.
Suspended particulates in air from heavy equipment/vehicles adversely affecting air quality	Dust suppression methods will be utilized on an "as needed" basis.
Vegetation removal for temporary road construction or existing road upgrades to accommodate heavy vehicles	Roads not required for the future OMM of the site will be excavated, backfilled with appropriate material and revegetated to blend in with existing cover/cap requirements.
Suspended sediment in surface water	Diversion dams/trenches, and geotextile silt fencing will be used to isolate surface water flows from active excavation areas. Sediment settling/retention ponds may be required.
Low-level radiation protection during excavation and transport of low-level radioactive slag	Low-level radiation exposure is not expected to exceed public dose limits and the action levels identified in the H&S Plan (CH2M HILL, January 2002). Implementation of simple dose limiting procedures described in the H&S plan will serve to minimize this exposure. No internal low-level radiation hazards expected.
Low-level radiation protection during excavation and transport of low-level radioactive tailings	Low-level radiation exposure is not expected to exceed public dose limits and the action levels identified in the H&S Plan (CH2M HILL, January 2002). Implementation of simple dose limiting procedures described in the H&S plan will serve to minimize this exposure. Dust suppression may be necessary under dry conditions. Controls to prevent contamination spread must be in effect, including monitoring equipment and personnel prior to leaving the active work area.

4.4 Implementation Schedule

Following acceptance of the final cleanup plan by the existing liaison committees, the public, and regulatory bodies, tender packages will be developed with the Management Board Secretariat, Shared Services Bureau (SSB) in such a way that it will be possible to issue a call for tenders for implementation of the work packages shortly after the delivery of the necessary permits and approvals.

The integrated cleanup plan will prioritize site-wide rehabilitation work packages based on the ability of an individual work package to lower contaminant loading rates, eliminate public health and environmental hazards, and facilitate the implementation of work packages in a logical manner.

The schedule has been arranged in a linear format and has not been assumed to run concurrently. Work programs are anticipated to commence in early April and extend as late as November. It is not anticipated that the work will be conducted in the winter months of

December to March. The contractor work plan will need to outline mitigating steps to be taken in order to minimize anticipated weather delays in the early and late months of the work periods. The scheduled operational periods of the year allow for sufficient slack time to account for deleterious weather conditions and other delays, and to allow for integration into the overall site-wide implementation schedule.

The rehabilitation program schedule is provided in Table 4.4 and spans a five-year period to complete the following main tasks in the time frames provided:

- Year 1 – Site Preparation and Demolition (Duration: 60 days)
- Year 2 – Riverbank Reconstruction (Duration: 47 days)
- Year 3 – North Industrial Area Rehabilitation (Duration: 102 days)
- Year 4 – South Industrial Area Rehabilitation (Duration: 125 days)
- Year 5 – Groundwater Interceptor Well Network and Revegetation (Duration: 100 days)

The work program will first address buildings, ruins and other structures that may impede the waste consolidation process. The riverbank reconstruction process must be completed before the waste consolidation work programs, as access routes to the riverbank will be limited when operations commence in the North and South Industrial Areas.

The rehabilitation of the North Industrial Area was sequenced prior to the South Industrial Area due to the required movement of slag materials from the South Industrial Area and to facilitate the continued operation of the groundwater collection and treatment system. As wastes in the North and South Industrial Areas are excavated and consolidated, the slag stockpiled in the Industrial Area will be used as backfill to within 65 cm of the proposed ground surface as shown in SEC-2 in Figure 3-8. It is anticipated that the slag on the site can be used to backfill most of the Industrial Area where excavations will extend deeper than 65 cm. The primary locations designated for slag backfill are Areas R, Q, V, and K. The sequencing of the South Industrial Area rehabilitation program is planned to allow for the transfer of slag into the considerable excavation anticipated in Area K. When the areas are backfilled to 65 cm bgs, simple earth (clay) caps will be applied to the North and South Industrial Areas.

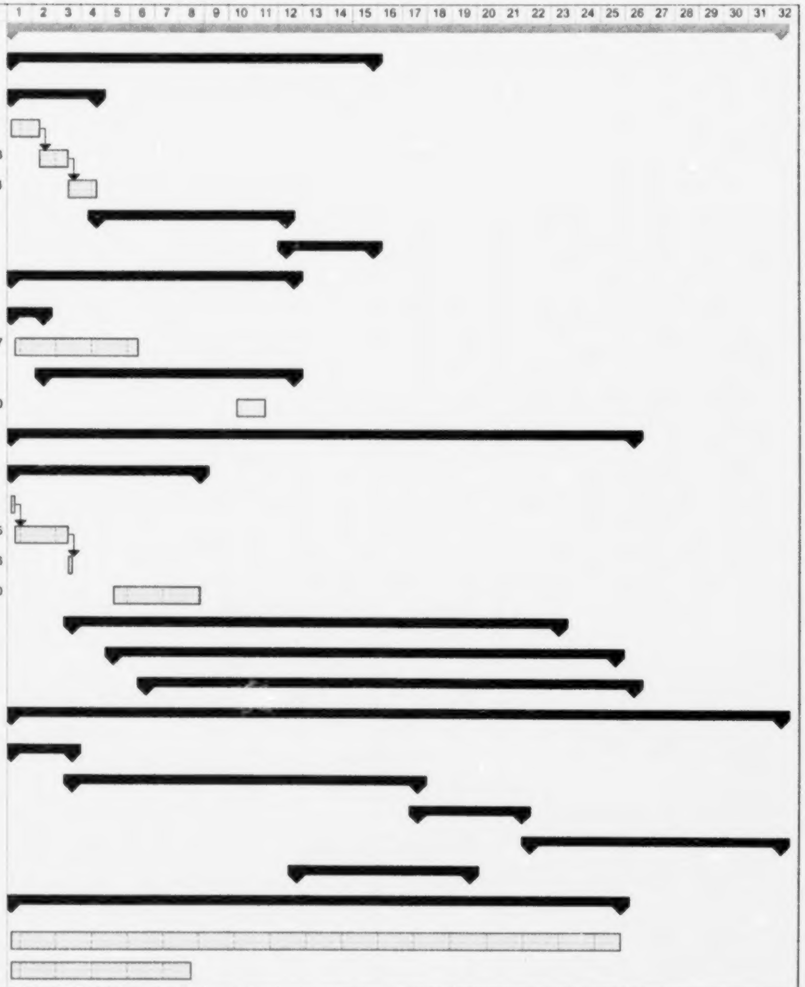
During years two to four, the wastes generated while rehabilitating the riverbank and the areas north and south of the engineered cover will be mounded in the central Industrial Area. As the wastes are mounded, a 50-cm clay cover will be progressively placed over the mound to minimize exposure to the wastes between construction seasons. When the mound is complete, the remaining layers of the engineered cover will be applied. This will allow for protection from the wastes, while integrating flexibility into the consolidation process in the event that significantly more wastes are identified and require the clay-covered mound to be reworked to accommodate them.

The GIWN will be installed west of the WCA following the completion of the engineered cover, so as to not impede the consolidation and cover placement process.

Following the placement of the topsoil layer on the engineered cover, the cover will be vegetated with grass, shrubs and poplar trees. Simple earth (clay) caps, SEC-1, SEC-2, and SEC-3, will be vegetated with grass and shrubs. SEC-4 under the main entrance to the site will be asphalted or remain a gravel surface.

If required, the rehabilitation program could be condensed to three years as shown in Table 4.5.

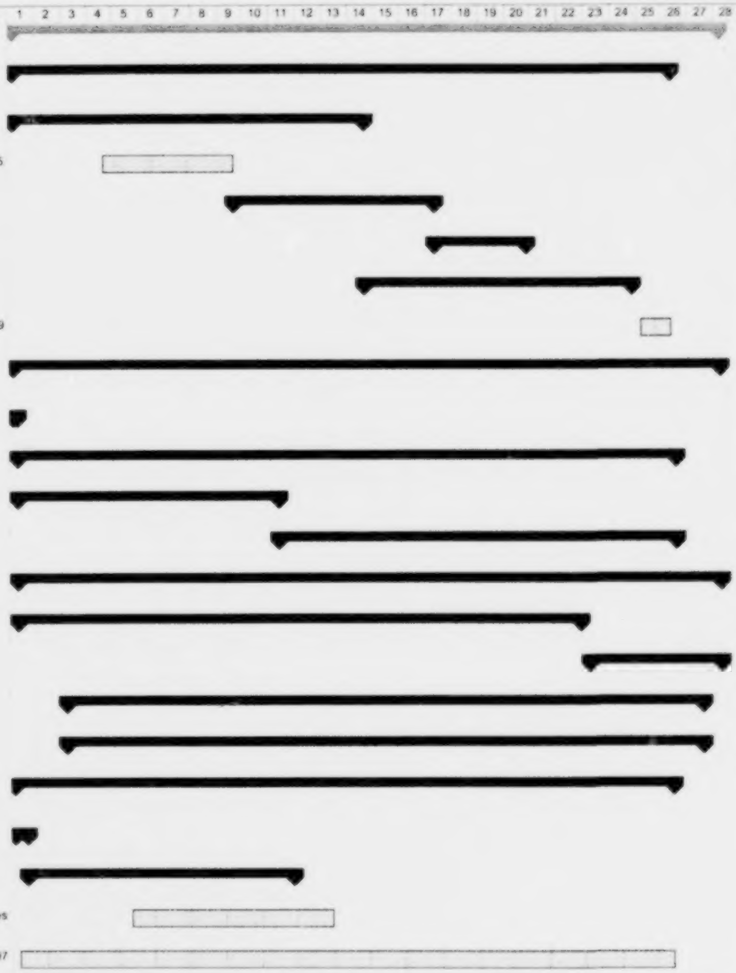
ID	Task Name	Duration	Start	Finish	Predecessors
0	**Table 4.4 - Industrial Area 5-Year Construction Schedule**	**125 days**	**Mon 04/02/07**	**Tue 11/06/07**	
1	**YEAR 1 - Site Preparation and Demolition**	**60 days**	**Mon 04/02/07**	**Fri 07/13/07**	
2	**IA-WP#1.1 - Year 1 Site Preparation**	**15 days**	**Mon 04/02/07**	**Thu 04/26/07**	
3	1.1.1 - Setup	5 days	Mon 04/02/07	Tue 04/10/07	
4	1.1.2 - Decontamination Pad	5 days	Tue 04/10/07	Wed 04/18/07	3
5	1.1.3 - Access Routes	5 days	Wed 04/18/07	Thu 04/26/07	4
6	**IA-WP#2.1 - Demolition of Buildings and Tanks**	**30 days**	**Thu 04/26/07**	**Tue 06/19/07**	
15	**IA-WP#2.2 - Resizing and Consolidation of Ruins**	**15 days**	**Tue 06/19/07**	**Fri 07/13/07**	
25	**YEAR 2 - Riverbank Reconstruction**	**47 days**	**Mon 04/02/07**	**Thu 06/21/07**	
28	**IA-WP#1.2 - Year 2 Site Preparation**	**6 days**	**Mon 04/02/07**	**Wed 04/11/07**	
30	**IA-WP#6.1 - Clay Berm Around Perimeter of Equalization Pond - 20 m/day**	20 days	Tue 04/03/07	Tue 05/08/07	27
31	**IA-WP#3 - Riverbank Reconstruction**	**41 days**	**Wed 04/11/07**	**Thu 06/21/07**	
42	**IA-WP#6.2 - 50 cm Clay Cover over Riverbank Wastes - 600 m2/day**	5 days	Tue 06/05/07	Wed 06/13/07	40
43	**YEAR 3 - North Industrial Area Rehabilitation**	**101.5 days**	**Mon 04/02/07**	**Tue 09/25/07**	
44	**IA-WP#1.3 - Year 3 Site Preparation**	**32 days**	**Mon 04/02/07**	**Fri 05/25/07**	
45	1.3.1 - Setup	1 day	Mon 04/02/07	Tue 04/03/07	
46	1.3.2 - Grubbing Trees and Vegetation in Cover and North Industrial Areas	9 days	Tue 04/03/07	Wed 04/18/07	45
47	1.3.3 - Well Decommissioning in North Industrial Area and Year 3 Cover Areas	1 day	Wed 04/18/07	Thu 04/19/07	46
48	1.3.4 - New Westerly Creek 500 m Culvert Extension	15 days	Tue 05/01/07	Fri 05/25/07	50
49	**IA-WP#4.1 - Consolidation of North Industrial Area Wastes - 1300 m3/day**	**78 days**	**Thu 04/19/07**	**Tue 09/04/07**	
68	**IA-WP#6.3 - 50 cm Clay Cover over NIA Wastes - 1000 m2/day**	**81.5 days**	**Tue 05/01/07**	**Thu 09/20/07**	
75	**IA-WP#5.1 - Simple Earth Cap Placement - 1000 m2/day**	**78.5 days**	**Thu 05/10/07**	**Tue 09/25/07**	
82	**YEAR 4 - South Industrial Area Rehabilitation**	**125 days**	**Mon 04/02/07**	**Tue 11/06/07**	
83	**IA-WP#1.4 - Year 4 Site Preparation**	**11 days**	**Mon 04/02/07**	**Thu 04/19/07**	
87	**IA-WP#4.2 - Consolidation of South Industrial Area Wastes - 1300 m3/day**	**56 days**	**Thu 04/19/07**	**Thu 07/26/07**	
96	**IA-WP#6.4 - 50 cm Clay Cover over SIA Wastes - 1000 m2/day**	**17 days**	**Thu 07/26/07**	**Fri 08/24/07**	
99	**IA-WP#6.5 - Place Remaining Layers of Engineered Cover**	**41 days**	**Mon 08/27/07**	**Tue 11/06/07**	
104	**IA-WP#5.2 - Simple Earth Cap Placement - 1000 m2/day**	**28 days**	**Fri 06/22/07**	**Fri 08/10/07**	
110	**YEAR 5 - GIWN & Revegetation**	**100 days**	**Mon 04/02/07**	**Fri 09/21/07**	
111	**IA-WP#7 - Groundwater Interceptor Well Network**	100 days	Mon 04/02/07	Fri 09/21/07	
112	**IA-WP#8 - Site Revegetation**	30 days	Mon 04/02/07	Wed 05/23/07	



Project: Table 4.4 - Industrial Area 5-Year Construction Schedule
Date: Thu 11/04/04

Task	▭	Progress	▬	Summary	▬	External Tasks	▭	Deadline	⇩
Split	┈	Milestone	◆	Project Summary	▬	External Milestone	◆		

ID	Task Name	Duration	Start	Finish	Predecessors
0	**Table 4.5 - Industrial Area 3-Year Construction Schedule**	**108.5 days**	**Mon 04/02/07**	**Mon 10/08/07**	
1	**YEAR 1 - Site Preparation and Demolition**	101 days	Mon 04/02/07	Tue 09/25/07	
2	**IA-WP#1.1 - Year 1 Site Preparation**	55 days	Mon 04/02/07	Thu 07/05/07	
9	**IA-WP#6.1 - Clay Berm Around Perimeter of Equalization Pond - 20 m/day**	20 days	Thu 04/26/07	Thu 05/31/07	5
10	**IA-WP#2.1 - Demolition of Buildings and Tanks**	38 days	Thu 05/31/07	Tue 07/24/07	
19	**IA-WP#2.2 - Resizing and Consolidation of Ruins**	15 days	Tue 07/24/07	Fri 08/17/07	
29	**IA-WP#3 - Riverbank Reconstruction**	41 days	Thu 07/05/07	Fri 09/14/07	
40	**IA-WP#6.2 - 50 cm Clay Cover over Riverbank Wastes - 600 m2/day**	5 days	Mon 09/17/07	Tue 09/25/07	39
41	**YEAR 2 - Waste Consolidation and Simple Earth Cap**	108.5 days	Mon 04/02/07	Mon 10/08/07	
42	**IA-WP#1.2 - Year 2 Site Preparation**	1 day	Mon 04/02/07	Tue 04/03/07	
44	**CREW 1**	101 days	Tue 04/03/07	Wed 09/26/07	
45	**IA-WP#4.1 - Consolidation of Industrial Area Wastes - 1300 m3/day**	40 days	Tue 04/03/07	Tue 06/12/07	
52	**IA-WP#5.3/6.4 - 50 cm Clay Cover over Wastes - 1000 m2/day**	81 days	Tue 06/12/07	Wed 09/26/07	
58	**CREW 2**	107.5 days	Tue 04/03/07	Mon 10/08/07	
59	**IA-WP#4.2 - Crew 2 Consolidation of Industrial Area Wastes - 1300 m3/day**	87 days	Tue 04/03/07	Fri 08/31/07	
80	**IA-WP#5.1 - Simple Earth Cap Placement - 1000 m2/day**	20.5 days	Mon [illegible]	Mon 10/08/07	
84	**CREW 3**	98 days	Mon 04/16/07	Wed 10/03/07	
85	**IA-WP#5.1 - Simple Earth Cap Placement - 1000 m2/day**	98 days	Mon 04/16/07	Wed 10/03/07	
95	**YEAR 3 - Cover, GIWN & Revegetation**	101 days	Mon 04/02/07	Tue 09/25/07	
96	**IA-WP#1.3 - Year 3 Site Preparation**	3 days	Mon 04/02/07	Thu 04/05/07	
99	**IA-WP#6.5 - Place Remaining Layers of Engineered Cover**	41 days	Thu 04/05/07	Fri 06/15/07	
104	**IA-WP#8 - Site Revegetation**	30 days	Thu 05/03/07	Tue 06/26/07	103FF+5 days
105	**IA-WP#7 - Groundwater Interceptor Well Network**	100 days	Tue 04/03/07	Tue 09/25/07	97



Project: Table 4.5 - Industrial Area 3-Year Construction Schedule
Date: Thu 11/04/04

Task	▭	Progress	▬	Summary	▬	External Tasks	▭	Deadline	⇩
Split		Milestone	◆	Project Summary	▬	External Milestone	◆		

The condensed program would require several crews working simultaneously:

- Demolishing buildings, consolidating ruins and reconstructing the riverbank in Year 1
- Consolidating wastes and covering with a 50-cm clay cover and placing simple earth (clay) caps in the North and South Industrial Areas during Year 2
- Completing the engineered cover and installing the GIWN concurrent with vegetating the Industrial Area with grass and poplar trees on the engineered cover in Year 3

4.5 Cost Opinion for Each Work Package

The estimated cost of each work package listed in Table 4.1, including a 15 percent contingency for capital costs, and overhead, bonds, and insurance costs, is provided in Table 4.6.

TABLE 4.6
WORK PACKAGE COSTS

Work Package Identification #		Description	Estimated Cost* (2004 dollars)
Capital Cost Items			
IA-WP#1		Site Preparation	$818,237
IA-WP#2		Demolition	$481,478
IA-WP#3		Riverbank Reconstruction	$831,012
IA-WP#4		Consolidation of Wastes	$913,535
IA-WP#5		Simple Earth (Clay) Cap	$4,025,504
IA-WP#6		Engineered Cover	$3,459,446
IA-WP#7		Groundwater Interceptor Well Network	$2,785,212
IA-WP#8		Site Revegetation	$253,595
		Total Capital Costs	**$13,568,019**
Operation, Maintenance, and Monitoring Cost Items (Annual)			
IA-OMM#1			
	1.1	Arsenic Treatment Plant Operations	$577,371
	1.2	Sludge Disposal (assuming 550 tonnes/year)	$177,131
	1.3	Site Maintenance and Monitoring	$146,408
	1.4	Groundwater Interceptor Well Network OMM	$26,468
		Total Annual (Weighted) OMM Costs	**$927,377**
Net Present Value of OMM Costs (includes remote location fees and overhead)			**$12,123,471****
Net Present Value of Capital and OMM Costs			**$25,691,490**

*All costs have been developed using 2004 pricing and do not include an escalation factor.

**Net Present Value (NPV) of Annual OMM Costs using an effective interest rate of 5 percent, and a planning horizon of 20 years.

The net present value (NPV) costs presented above are the sum of the capital cost and the net present value of the OMM costs for 20 years following the completion of work. The annual weighted OMM costs have been transformed to a net present value assuming an effective interest rate of 5 percent and a planning horizon of 20 years. The effective interest rate includes inflationary effects. It should be noted that OMM efforts and costs will likely be required beyond the 20-year horizon. The 20-year period was selected based on the assumption that it is a reasonable period for budgetary planning purposes.

As shown above, the estimated capital cost of the Closure Plan is $13,568,019 with annual weighted OMM costs of $927,377. The costs provided do not include engineering consulting fees, except for the OMM budgets. The net present value of the Closure Plan is $25,691,490. The costs presented in the above table include overhead, remote location costs, federal Goods and Services Tax (GST), a 15 percent contingency for the capital costs, a 5 percent contingency for the OMM costs, and the cost of various construction bonds and insurance associated with the work. With the exception, GST was not applied to the cost for the ATP operations, which will continue to be conducted by OCWA. The costs presented are expected to have accuracy on the order of +/-25 percent.

As noted in Section 3.4.1, consolidation, grading, and covering/capping of the Industrial Area will affect existing pumping stations, inspection holes, monitoring wells, and the overland forcemain from the Tuttle Shaft. The pumping stations, inspection holes, and wells will require modification to extend these to the new final grade. The existing forcemain from the Tuttle Shaft will be replaced with a new above ground pipeline as detailed and costed in the Mine Area Closure Plan. The capital cost to undertake the other modifications in the Industrial Area are not included in Table 4.6 since related evaluation and design is beyond the scope of this Closure Plan. The modifications required for the existing pumping stations, inspection holes, and monitoring wells will be addressed as part of the final design.

As noted in Section 3.5.5 and shown in Figure 3-15, future flows to the ATP will likely decrease to approximately 198 m^3/day. However the cost opinion for the ATP operations (Table 4.6) is conservatively based on the current annual cost resulting from the current treatment rate of approximately 274 m^3/day.

The capital cost of the GIWN (Table 4.6) was based on the current understanding of groundwater flow in the bedrock at the site and will be refined following further hydrogeological field investigations and groundwater flow modelling proposed to be completed in 2004.

The capital cost of the GIWN (Table 4.6), consisting of a horizontal well in bedrock, vertical pressure relief wells and vertical access shafts (see Section 3.5.2), may potentially be reduced if future modelling and design work identifies a similar but more cost-effective approach. For example, construction of a horizontal tunnel instead of a horizontal well may be more cost effective, since vertical shafts are not needed to allow the connection of the vertical wells to the horizontal well (The vertical pressure relief wells could be drilled directly through the constructed tunnel). However, as described in Section 3.5.2, the construction of vertical shafts, as part of the horizontal well solution, provides the opportunity for future access, if desired, for monitoring and more refined operation of the horizontal well.

Also, as noted in Section 3.4.1, depending on the data obtained during the upcoming hydrogeological field investigation, additional modelling should also include evaluation of a horizontal well constructed entirely in the overburden, in conjunction with vertical pressure relief wells constructed in the bedrock, to determine if effective groundwater flow control can be achieved. Depending on the results of these evaluations, this may potentially lead to a more cost-effective GIWN than the cost opinion presented in Table 4.6 (based on a horizontal well in bedrock and vertical pressure relief wells to completely dewater the surficial deposits beneath the WCA).

A detailed breakdown of the estimated costs associated with each work package tasks and subtasks is provided in Appendix B. The costing in Appendix B is based on the cost opinion originally expressed in the Industrial Area Rehabilitation Alternatives report (CH2M HILL, December 2003a), which has been modified and completed to the preliminary design level, with the exception of the costing for the GIWN which has been completed to the conceptual design level.

Costs are itemized into unit, estimated quantity, unit price, and total categories. Each work package is subdivided into tasks and subtasks, coinciding with a planned schedule. The unit costs include labour, equipment rates, fuel, and materials. Unit costs have been based on prices acquired from regional contractors where available. If a regional contractor was not available a suitable alternate was determined, taking into consideration mobilization and demobilization costs. Delivery of materials to Deloro was included in the rates.

Site preparation will include access road rehabilitation, office trailers, decontamination trailers, a decontamination pad, and grubbing of trees and vegetation to expose the wastes and soils prior to excavation.

The cost estimates for the demolition phase were based on site visits and photographs taken during prior site investigations. The lump sum prices have been determined on the number of machine hours that would be necessary to complete the work. A site visit with a demolition expert for budgetary purposes would be necessary to more accurately estimate the actual costs.

Unit rates of excavation were determined based on hourly costs of machines and pre-determined work-rates for the machinery. Budgets are entirely dependent on the volume of material to be excavated and compacted, not the time required to complete the work.

The unit rates for the supply of engineered cover and simple earth (clay) cap materials, in particular the clay, is based on currently available resource information. Prior to the implementation of the construction program, the cost of these materials will be refined.

Table 4.7 summarizes the costs of work package tasks in the order of their year of completion.

TABLE 4.7
YEARLY PROJECT COST AND IMPLEMENTATION PLAN

Package I.D.	Work Package Description	Estimated Cost
Year 1 – Site Preparation and Demolition		
IA-WP#1.1	Site Preparation	$ 231,544
IA-WP#2.1	Demolition of Buildings and Tanks	$ 237,341
IA-WP#2.2	Resizing and Consolidation of Ruins	$ 244,136
	Year 1 Capital Costs	**$ 713,022**
Year 2 – Riverbank Reconstruction		
IA-WP#1.2	Site Preparation	$ 63,513
IA-WP#6.1	Clay Berm Around Perimeter of Equalization Pond	$ 80,934
IA-WP#3	Riverbank Reconstruction	$ 831,012
IA-WP#6.2	50 cm Clay Cover over Riverbank Wastes	$ 95,735
	Year 2 Capital Costs	**$ 1,071,194**
Year 3 – North Industrial Area Rehabilitation		
IA-WP#1.3	Site Preparation, including the NWC 500 m Culvert Extension	$ 397,146
IA-WP#4.1	Consolidation of North Industrial Area Wastes	$ 507,988
IA-WP#6.3	50 cm Clay Cover over North Industrial Area Wastes	$ 758,449
IA-WP#5.1	Simple Earth (Clay) Cap Placement in North Industrial Area	$ 2,089,588
	Year 3 Capital Costs	**$ 3,753,170**
Year 4 – South Industrial Area Rehabilitation		
IA-WP#1.4	Site Preparation	$ 126,034
IA-WP#4.2	Consolidation of South Industrial Area Wastes	$ 405,548
IA-WP#6.4	50 cm Clay Cover over South Industrial Area Wastes	$ 318,182
IA-WP#6.5	Placement of Remaining Layers of Engineered Cover	$ 2,191,159
IA-WP#5.2	Simple Earth (Clay) Cap Placement in South Industrial Area	$ 1,950,904
	Year 4 Capital Costs	**$ 4,991,826**
Year 5 – Groundwater Interceptor Well Network and Revegetation		
IA-WP#7	Groundwater Interceptor Well Network	$ 2,785,212
IA-WP#8	Site Revegetation	$ 253,595
	Year 5 Capital Costs	**$ 3,038,807**
	TOTAL CAPITAL COSTS	**$ 13,568,019**

4.6 Health Hazard Assessment

A document entitled *Deloro Mine Rehabilitation Project – General Health and Safety Plan (GHASP), Final Report* (CH2M HILL, January 2002) has been developed to identify the main hazards and to provide a basis for the health and safety protocols.

The GHASP identifies the following health hazards associated with the Deloro Mine Site that could be encountered while undertaking site inspections, site investigations, and remedial cleanup:

- Arsenic and arsenic compounds, other metals, and silica
- Radiological hazards
- Heat and cold stress
- Buried utilities
- General physical (safety) hazards
- Biological hazards
- Chemicals existing at or brought onto site

The GHASP outlines and describes appropriate procedures and protocols to effectively deal with the above hazards associated with the Deloro Mine Site. The GHASP addresses hazard evaluation and control procedures and protocols (including action levels), personal protective equipment to be used, air monitoring protocols and specifications, decontamination procedures and protocols, spill containment procedures, confined space entry procedures, emergency response plans, and emergency contacts.

Addenda to the GHASP will address hazards associated with specific work packages identified in this and the other three Closure Plans.

Radiological hazards result from low-level radioactive slag and some tailings-like material in the Industrial Area, and sediments in the onsite Young's Creek Area contaminated by radium and uranium tailings eroded from the Tailings Area. The slag represents an external hazard from low-level radiation fields, whereas the tailings-like material and sediments represent both external hazards due to low-level radiation fields and internal hazards from potential ingestion and/or inhalation during the handling activities. Although ambient low-level radiation fields in most of the work areas are expected to be below 1 μSv/h, standard low-level radiation protection procedures as described in the GHASP will be employed to minimize doses to workers during the various remediation activities. Routine low-level radiation field monitoring will be used to identify those areas in which low-level radiation protection procedures must be implemented. Contamination control procedures will also be implemented as described in the GHASP. Decontamination procedures are outlined in Section 4.7.4 of this Closure Plan.

4.7 Environmental and Community Health Protection Plan

Potential receptors that could be affected by the cleanup of the Deloro Mine Site include workers involved in the site cleanup, residents in the Village of Deloro, residents and cottagers along the Moira River downstream of the site, and vehicular traffic along Highway 7 near Young's Creek (in the case of impacted materials to be transported onsite from offsite Young's Creek across Highway 7). The following ECHPP identifies potential risks associated with the cleanup of the site and recommends appropriate mitigation measures. Protection of workers involved in the site cleanup was addressed in Section 4.6.

The disturbance of potentially contaminated materials during remedial activities and the possible loss of contaminants from the work area depend to a high degree on the remedial methods and related physical activities undertaken during site rehabilitation. Since the transport of contaminants is most easily controlled at the source, the remedial activities selected for the site have been chosen based on the ability to minimize and control the disturbance, spread and loss of contaminants from the work area. Additional actions can be taken to further limit the spread and loss of contaminants from the work area and potentially offsite. These include measures to control dust, noise, odours, surface water runoff, surface water run-on, and erosion, as well as the use of appropriate equipment and personnel decontamination procedures. Each of these measures, which are discussed briefly below, will be undertaken prior to and during implementation of the remedial activities. Odour control is not discussed since it is not expected to be of concern during implementation of remedial activities at the Deloro site.

It should be noted that this overview provides some of the key aspects associated with the mitigation and monitoring of potential offsite impacts resulting from remedial activities at the Deloro site. The finalized details and procedures will be included in the contract documents and specifications associated with the rehabilitation of the Deloro site, and the execution plans proposed by the remedial contractors who are selected to complete the cleanup work.

4.7.1 Dust Control and Air Monitoring

Effective dust control at sites undergoing remediation is best addressed via the development, establishment, implementation and enforcement of a fugitive particulate emission control program. The development and implementation of such a program is generally the responsibility of the remedial contractor and is required to be reviewed and approved by the owner and/or the consultant. The fugitive particulate emission control program includes a description of the procedures relating to the handling of materials, air monitoring and dust control, and is documented in the contractor's execution plan for the site remedial activities. The remedial contractor is required to take all precautions necessary to minimize and control the generation of dust and under no circumstances will unacceptable levels of dust be permitted to be generated and/or transported offsite.

Key aspects of a fugitive particulate emission control program include:

- Carrying out remedial activities that involve disturbance of material, such as excavation, during good weather conditions in order to minimize the loss of materials by wind.
- Movement of materials directly to their designated location, rather than handling several times, in order to minimize the generation of dust (i.e. multiple handling tends to break materials into smaller and smaller pieces which are more likely to be entrained by wind).
- Ensuring adequate equipment and personnel are available at the site at all times to immediately clean up any spilled material, whether it be of a small or large amount.
- An inspection program to monitor the condition of onsite and offsite roads, materials piles, vehicles, etc.
- The use of tarps to cover materials which are likely to generate dust.
- The use of dust suppressants to control dust associated with roadways, work area, stockpiles and other possible sources. Materials used to assist in dust suppression might include water, calcium chloride or latex binders. The frequency of application of dust suppressants is generally on an as-needed basis.

- Regrading of unpaved roads, as required, to keep silt content below 10 percent, and the sweeping of paved roads.
- The use of tarps on trucks used to transport materials onsite and offsite.
- In the case of the Deloro site cleanup, air monitoring both upwind and downwind of the site will be carried out in order to confirm that dust control measures are effective, and to ensure that any potential offsite air quality impacts caused by remedial operations are minimized. Monitoring should be carried out for dustfall and total suspended particulate (TSP). Monitoring for arsenic and other selected metals should also be considered. Although in the handling of low-level radioactive tailings, low-level radioactive contaminants may become airborne, the expected levels will be considerably less restrictive than those for arsenic at similar TSP concentrations.
- The frequency of monitoring and location of monitoring stations at the Deloro site will be determined following the development of the final integrated cleanup plan, and the review of the contractor's execution plan, the proposed remedial activities and meteorological conditions. Typically, TSP is measured using standard high-volume samplers and a daily (24-hour) average determined. Depending on the size of the site, samplers are typically located at four upwind/downwind perimeter sites during each work day. Their location is subject to change based on the location of remedial activities, but they are generally placed at the furthest possible distance downwind of the site within the property line. Standard dustfall jars are used to obtain dustfall measurements, which are typically determined based on a 30-day integrated measurement of dustfall loadings at four perimeter locations.
- Meteorological measurements (wind speed and direction) may also be required to be carried out in conjunction with the air monitoring program. Typically, hourly and daily average wind speed and direction at one localized site could be required during site activities.
- The MOE Ambient Air Quality Criteria (AAQC) for dustfall is 7 g/m^2 (30-day AAQC) and for TSP is 120 $\mu g/m^3$ (24-hr AAQC). The AAQC for TSP and dustfall were determined with nuisance effects being the limiting factor. Health effects are not a concern until TSP levels are several times higher than defined by the AAQC, unless elevated concentrations of arsenic and/or other metals are present in the dust. Levels in excess of these criteria, on the basis of property line monitoring results, are considered unacceptable. In instances where background or upwind concentrations exceed these criteria, additional contribution to the parameter is also normally considered unacceptable.
- Monitoring of ambient air quality prior to initiation of remedial activities at the Deloro site is recommended and should be carried out on several occasions and under a variety of conditions in order to establish background air quality both onsite and offsite.

4.7.2 Noise Control

While noise is expected to be generated at the Deloro site during cleanup as a result of mobile sources such as truck and vehicular traffic, as well as equipment sources such as excavators, bulldozers, compactors, generators, pumps and air compressors, conformation with regulatory requirements is not expected to be a major problem. The development and implementation of a noise monitoring and control program is generally the responsibility of the remedial contractor and is required to be reviewed and approved by the owner and/or the consultant prior to initiation of any site work. The contractor is usually required to provide written details of the noise monitoring and control program in their execution plan to ensure that local requirements are met.

Typical aspects of a noise monitoring and control program include:

- The contractor will be required to take all precautions necessary to minimize noise and under no circumstances will unacceptable levels of noise be permitted to impact offsite residents/property owners.
- The contractor is to conduct all work using appropriate construction methods and equipment so that noise emanating from the site remains at acceptable levels.
- The contractor is required to obtain approval from the owner and/or consultant prior to conducting any site activities between the hours of 6:00 p.m. and 7:00 a.m.
- The contractor will be required to undertake noise monitoring if deemed necessary.
- MOE noise guidelines for landfill operations suggest that a criterion of 50 dBA during the hours of 7:00 a.m. and 7:00 p.m. should be established for the closest residential location. A similar guideline may be suitable for the cleanup activities at the Deloro site.

4.7.3 Surface Water Protection

The control of surface water is required in order to minimize the contact of water with potentially contaminated materials and thus reduce the generation of contaminated water. This can be achieved though the control of surface water runoff from the work area, as well as the control of surface water run-on into the work area. Surface water is also required to be controlled in order to minimize erosion and prevent the offsite transport of potentially contaminated water and sediment to Young's Creek and the Moira River. Specific details relating to the control of surface water will be dependent on the final engineering designs for the cleanup of the site.

The development and implementation of a work area surface water control program is generally the responsibility of the remedial contractor and is required to be reviewed and approved by the owner and/or the consultant. Generally, the remedial contractor is required to take all precautions necessary to minimize the generation of sediment and potentially contaminated surface water and may be required to collect and treat any such water.

Key aspects of a work area surface water control program include:

- The use of geotextile silt fencing, sand bags and/or straw bales to reduce sediment transport.
- The construction of surface water diversions, comprised of swales and sumps or clay berms, to re-direct and/or collect surface water runoff and run-on.
- The collection and treatment of all potentially contaminated water, including water used to decontaminate equipment, surface water and water generated from the dewatering of excavations.
- In the case of the Deloro site cleanup, surface runoff characteristics (e.g. quantity, quality, and direction of flow) of the site should be assessed prior to initiation of

remedial activities. Additionally, an assessment of the quality of water in existing site drainage ditches and channels, including those that result in both run-on and runoff, standing water and natural water (e.g. any adjacent natural streams, wetland areas, and the Moira River) should be undertaken prior to remedial activities (if not addressed through current site monitoring). The water quality assessment should include the sampling and analysis of water for total suspended solids, arsenic, and metals.

- Once a decision on the activities planned for the Deloro site is made, a site-wide surface water quality monitoring program should be developed for implementation during the cleanup.

4.7.4 Decontamination Procedures

In order to prevent the transfer of contaminants from the work area, all equipment, materials, and supplies that come into contact with potentially contaminated materials must be decontaminated prior to removal from the work area. The development and implementation of equipment decontamination procedures is generally the responsibility of the remedial contractor and is required to be reviewed and approved by the owner and/or the consultant. The remedial contractor is required to take all precautions necessary to minimize the transfer of contaminated materials from the work area. Under no circumstances is the transfer of non-decontaminated equipment and materials from the work area permitted.

The key aspects of a decontamination program include:

- Decontamination of equipment and materials that have come into contact with potentially contaminated materials, completed by the contractor prior to the removal of equipment and materials from the work area.
- Equipment decontamination using water or steam facilities to decontaminate tracks, sprockets, tires, axles, buckets, and trailers used in the transport of materials.

CH2M HILL has prepared a conceptual design for a decontamination facility to be constructed and operated by the remedial contractors.

4.7.5 Emergency Response and Preparedness

CH2M HILL will develop a site-specific emergency procedures plan including requirements and information relating to emergency contacts, directions to the nearest hospital, spill and fire control, emergency communications, emergency response such as for a spill or fire, medical emergency procedures, notification, and reporting. All site contractors will be expected to be familiar with and implement the site-specific emergency procedures plan as required. Much of this information is already contained in the GHASP (CH2M HILL, January 2002).

4.7.6 Associated Considerations and Activities

Several issues associated with the mitigation of offsite impacts include:

- As previously noted, CH2M HILL will develop a site TERP to outline procedures and protocols for addressing vehicular accidents and spills of hazardous and non-hazardous materials. Procedural controls will limit the speed of vehicles and determine safe routes.

- The development and implementation of specific work practices associated with contamination, decontamination, and clean work zones.
- In addition to the existing perimeter fencing, the development and implementation of a site security plan including aspects such as additional fencing of work areas, warning/caution signs, security patrols, control of site staff and visitors, etc.
- The use of a qualified environmental contractor who is experienced in similar types of projects, has a good safety and environmental record, and whose employees are experienced and qualified.

4.8 Other Operational Procedures

In order to prevent the spread of contamination during the excavation of the low-level radioactive tailings-like material, the approximately 1,200-m^2 area will be surrounded by a berm, constructed to contain any contamination during rainfall events. The highest levels of radium contamination, located in the eastern portion of the old lagoon, likely represent only two or three truckloads. Procedural controls will ensure that this material is not excavated during precipitation events.

Since the low-level radioactive constituents in the low-level radioactive slag are immobile, low-level radioactive releases from this waste are not likely to occur during rainfall events.

5. Operation and Maintenance Requirements

The operations and maintenance requirements are addressed in Section 5, while the monitoring requirements are addressed in Section 6. Collectively, these requirements are referred to as operations, maintenance and monitoring (OMM).

A detailed OMM plan and manual should be established for the Industrial Area following the implementation of the rehabilitation measures. OMM of the rehabilitation measures will be required to ensure that they remain in good working order.

OMM efforts under the recommended alternative would be associated primarily with the ongoing operation of the ATP and groundwater collection and treatment system currently maintained by OCWA, the operation of the GIWN and the periodic maintenance of the poplar trees, simple earth (clay) caps, engineered cover, GIWN, surface water drainage ditches, riverbank and perimeter fence.

Monitoring programs to identify the need for maintenance are discussed in Section 6.

5.1 Arsenic Treatment Plant

The ATP and associated infrastructure is presently maintained by OCWA on behalf of the MOE. It is anticipated that OCWA will continue to manage the system into the foreseeable future.

5.2 Groundwater Collection and Treatment System

The overland conveyance system for the pumping stations and the GIWN may require periodic flushing and cleaning. Pipe integrity testing by regular pressure testing will be required. Regular pump maintenance, such as routine seals replacement, will be as specified by the pump manufacturer.

Routine maintenance of erosion on the equalization pond berm will also be required.

5.3 Poplar Trees

In the short-term (first three years), maintenance requirements will include watering of planted/treed areas as required to maintain plantation health, replacing plants as needed, checking for tree health, and addressing rodent activity (beaver and vole controls). Mowing between tree rows will reduce competition among the trees and expose rodents to predators. These activities will help to ensure that the freshly vegetated areas have a low mortality rate and that vegetation density increases to the required level.

5.4 Simple Earth (Clay) Caps and Engineered Cover

Periodic maintenance of the simple earth (clay) caps and engineered cover will be required to repair erosion damage and areas of vegetative stress.

Drainage ditches graded into the simple earth (clay) caps or engineered cover will require routine maintenance to protect against erosion.

5.5 Riverbank

The reconstructed riverbank may require maintenance following storm events that damage the rip/rap along the shoreline. Additional features to prevent the erosion of the riverbank at the outfall of the horizontal well conveyance pipe may be required.

5.6 Perimeter Fencing

A maintenance program to inspect and maintain the integrity of the perimeter fence will address the following activities on a semi-annual basis:

- Removal of dead trees that may otherwise collapse and damage the perimeter fence
- Removal of beaver dams, which are causing surface water control problems, including follow-up inspections to ensure they are not reconstructed
- Routine inspections to identify any other problems in regards to the fence integrity including identification of missing or damaged signs

The MNR should be contacted in the event large mammals become trapped inside the perimeter fence, to determine a suitable course of action.

6. Monitoring Program

A comprehensive monitoring plan will be required to evaluate the effectiveness of the cleanup measures and to identify the need for maintenance tasks discussed in Section 5. The physical and chemical stability, water quality, and biological features in the Industrial Area will be monitored in phases during two site rehabilitation time frames:

- Construction Phase
- OMM Phase

Monitoring may occur daily, weekly, or monthly or at other specified intervals. It is anticipated that sampling frequency will be gradually reduced as monitoring programs confirm the effectiveness of the rehabilitation measures in reducing the flux of arsenic migrating to the Moira River.

The results of monitoring during construction activities should be documented in a Site Closure Report. During the OMM phase, annual reports should be prepared that document the results of monitoring activities for that year, discuss past trends in the data, and forecast trends for the future. The overall effectiveness of the cleanup measures will be examined in the annual reports.

Various components associated with the monitoring program are described in detail below.

6.1 Physical Stability

Physical stability monitoring will be required for the three phases of site rehabilitation. A description of the monitoring programs for each phase is discussed below.

6.1.1 Monitoring Programs during the Construction Phase

Following design specifications during the construction phase will enhance the physical stability of site features. The following activities will require monitoring during the construction phase:

- Selection and characterization of suitable soils for the engineered cover, simple earth (clay) caps and backfill
- Placement, compaction and grading of consolidated wastes, layers of engineered covers, simple earth (clay) caps, and the reconstructed riverbank
- Placement of the rip/rap along the reconstructed riverbank
- Installation of the geosynthetic clay liner within the engineered cover and SEC-4
- Installation of the geotextile filter within the reconstructed riverbank, SEC-2 and SEC-3
- North extension of the culvert in New Westerly Creek
- Installation of the GIWN
- Revegetation of the Industrial Area with poplar trees and grasses

6.1.2 Monitoring Programs during the OMM Phase

Following the construction phase, monitoring the physical stability of existing and newly constructed site features in the Industrial Area will be required as part of the ongoing OMM phase. Table 6.1 lists the physical stability monitoring required during OMM.

TABLE 6.1
PHYSICAL STABILITY MONITORING DURING THE OMM PHASE

Site Security

- Examine the condition of the site fence, gates, gate locks, and signage

Surface Water Drainage Ditches

- Inspect ditches for: erosion especially on steep sections and downstream of confluence points; accumulation of sediment, ice, and debris that can result in blockages; beaver activity

New Westerly Creek and Culvert

- Inspect the NWC for: erosion especially downstream of the outfall; if possible, for internal deformation of culvert; accumulation of sediment, ice, and debris at the inlet and outfall of the culvert that can result in blockages; beaver activity

Engineered Cover and Simple Earth (Clay) Caps

- Inspect for: slope stability; tension cracks at the crest of slopes; signs of new or ongoing slope failure; gully and wind erosion; vegetation cover growth, stress, and stability; seepage along the side slopes; seepage stains; alluvial fans at the base of slopes; piping; bulging of slopes; and sloughing of crest
- Measure liner leakage (i.e. infiltration) using Time Domain Reflectometry (TDR) probes or equivalent
- Survey and/or instrument if critical-rates of slope movement or settlement are reached
- Sample seeps for metals and arsenic
- Periodic low-level radiation field surveys of the engineered cover and simple earth (clay) caps over low-level radioactive slag can give an indication of the cap/cover integrity. A low-level radiation survey near significant cracks may identify unshielded low-level radiation fields
- Inspect collector pipes in SEC-4, if possible, for internal deformation and blockages

Groundwater Collection and Treatment System

- Equalization pond: routine OMM by OCWA; visually inspect the pond and surrounding berm for erosion, cracks, burrowing animals (e.g. gopher holes, fox den); test pond for leakage to water table
- ATP: routine OMM by OCWA
- Piping, manholes, and pumps: routine OMM by OCWA
- Groundwater interceptor well network: routine OMM of flows and piping by OCWA; inspect horizontal and pressure relief well integrity and repair damaged wells; properly decommission damaged or unused wells

Monitoring frequency will vary from feature to feature. Elements of the groundwater collection and treatment system may require daily or weekly physical stability monitoring by OCWA. However, most site features will require monthly to semi-annual monitoring for the first five years following implementation of the Industrial Area rehabilitation measures. Following the initial five years, monitoring frequency could be reduced to annual, provided that the results do not identify adverse impacts to surface water quality.

6.2 Chemical Stability and Water Quality

The current monitoring program (surface water, groundwater, pumping system, ATP inlet and outlet) will be extended to monitor the effectiveness of the site rehabilitation measures.

6.2.1 Existing Monitoring Programs

An extensive monitoring program is currently conducted by OCWA to monitor the quality of surface water, groundwater and ATP effluent at the Deloro site. The existing sampling protocols discussed below were provided by OCWA in January 2004 (OCWA, January 2004).

Arsenic Treatment Plant

The raw influent and final effluent from the ATP is analyzed for arsenic daily when the ATP is operating.

Pumping Stations

Groundwater samples are collected monthly from the six pumping stations (PS#1 to PS#6) and the two groundwater inspection holes and tested for aluminum, arsenic, cobalt, copper, lead, mercury, molybdenum, nickel, and zinc.

Groundwater Monitoring Program

Groundwater within the Industrial Area has been sampled on a regular basis since 1988. Presently, there are 68 monitoring wells in the Industrial Area, which are sampled quarterly.

The 44 GA- and GR- series of monitoring wells are analyzed for aluminum, arsenic, cobalt, copper, lead, mercury, molybdenum, nickel, zinc, pH, conductivity, and height.

The 24 MW-97, MW-98, and 97-TL series of monitoring wells with piezometer tubes are analyzed for height, temperature, pH, dissolved oxygen, conductivity, redox (EMF), total cyanide, ICP, and hydride metals.

The 98-6t series of monitoring wells with piezometer tubes are monitored for height only.

Several of the wells are no longer operational, while others are occasionally dry.

Surface Water Monitoring Network

The Moira River monitoring network, shown in Figure 3-14, comprises 20 sampling stations on the Moira River, New Westerly Creek and Young's Creek that provide information on surface water quality upstream, downstream, and within the site boundary.

There are 12 sampling stations listed in Table 6.2 which are adjacent to the Industrial Area. All 12 stations are sampled weekly and analyzed for aluminum, arsenic, and nickel, with additional analyses for cobalt and copper at stations Stn 6, DM 6, DM7/Highway 7 and Gatling Shaft. The Gatling Shaft and DM 6 are also analyzed for lead, molybdenum, and zinc. All the stations are sampled monthly for mercury and quarterly for aluminum, arsenic, cobalt, copper, mercury, molybdenum, nickel, lead, and zinc. In addition, the Moira River at Highway 7 is analyzed for arsenic with a 28-day sampler that is repeated every 28 days.

TABLE 6.2
MOIRA RIVER MONITORING NETWORK

Station	Location
Stn 1	Station 1 is located on the river upstream of the Deloro site
Gatling	Samples are collected from the Gatling Shaft runoff to the river
Stn 2	Station 2 is located at the river between the Gatling and Tuttle Shaft stations
Tuttle	Samples are collected from the Tuttle Shaft runoff to the river
Stn 3	Station 3 is located downstream of the Tuttle Shaft and above the falls east of the boarding house ruins
Stn 4	Station 4 is located immediately upstream of the weir south of the mine site bridge
DM 6	Samples are collected from the runoff west of the concrete west tailings dam wall
Stn 320	Samples are collected from the runoff through the old equalization pond and dump
NWC	Samples are collected from the New Westerly Creek runoff to the river
Stn 5	Station 5 is located approximately 100 m downstream of the NWC station
Stn 6	Station 6 is located approximately 200 m downstream of Station 5
Hwy7/DM7	Highway 7 and the Moira River represents the downstream point for the Moira River; DM7 represents the upstream Moira River point for Young's Creek contribution

6.2.2 Monitoring Programs during the Construction Phase

With the following modifications, the current monitoring program (surface water, groundwater, pumping system, ATP inlet and outlet) will be extended into the construction phase to monitor the impacts of construction activities during the site rehabilitation.

Arsenic Treatment Plant

During construction, the raw influent and final effluent from the ATP will continue to be analyzed for arsenic daily when the ATP is operating.

Pumping Stations

During construction, the groundwater samples will continue to be collected monthly from the six pumping stations (PS#1 to PS#6) and the two groundwater inspection holes and tested for aluminum, arsenic, cobalt, copper, lead, mercury, molybdenum, nickel, and zinc.

Occasional interruption in pumping, and therefore sampling, is anticipated during modifications to the stations.

Groundwater Monitoring Program

Most, if not all, of the existing 68 monitoring wells will be decommissioned during the rehabilitation program. However, wells will only be decommissioned when the presence of the wells interfere with the excavation or consolidation activities, which will be completed over several years.

Therefore, during construction, the 68 monitoring wells in the Industrial Area will continue to be sampled quarterly for the parameters listed in Section 6.2.1, until the wells are decommissioned.

Surface Water Monitoring Network

The 12 sampling stations listed in Table 6.2 will continue to be sampled weekly/monthly/ quarterly and analyzed for the parameters listed in Section 6.2.1. The Moira River at Highway 7 will continue to be analyzed for arsenic with a 28-day sampler.

However, during periods of active excavation work in the Industrial Area (e.g. waste consolidation, cover/cap placement, riverbank reconstruction), surface water samples should be collected daily from Stations No. 3, 4, 9, 320, New Westerly Creek, and temporary stormwater retention ponds and analyzed for arsenic, metals, and suspended solids. The results should be compared to surface water concentrations of upstream sampling Stations No. 1 and 2, the PWQOs, and historical pre-excavation concentrations to assess the effectiveness of the surface water protection measures.

Sediment Monitoring Program

During construction, monitoring of sediment quality will be required to assess the impacts during excavation and consolidation activities on the Moira River.

Prior to, during, and following the riverbank reconstruction activities, sediment quality in the river should also be monitored to assess whether additional controls are required to limit the effect of construction activities on the Moira River.

Sediment samples should be analyzed for arsenic and metals.

6.2.3 Monitoring Programs during the OMM Phase

It is expected that groundwater extraction and treatment will probably not vary in the short term and that significant arsenic loading to the Moira River will persist until the new hydrogeological regime is established. Future monitoring of ATP influent and effluent, surface water, groundwater, and sediment quality at selected locations will evaluate the effectiveness of the recommended alternative following implementation.

Monitoring programs will identify trends:

- To determine the short- and long-term effects of the rehabilitation program on the Moira River water and sediment quality
- In groundwater quality and water table elevations in the Industrial Area after implementation of the GIWN and infiltration reduction measures
- In the quality and quantity of the influent treated by the ATP to assess the effects of the rehabilitation program, the ATP treatment efficiency, and the ability of the ATP to treat decreased influent volumes

The current monitoring program (surface water, groundwater, pumping system, ATP inlet and outlet) will be continued into the post-rehabilitation OMM phase for five years to monitor the effects of rehabilitation measures. Following the initial five years, monitoring frequency of pumping stations could be reduced to quarterly and the surface water and groundwater could be reduced to semi-annual or annual, provided that the results do not identify adverse impacts to surface water quality.

Arsenic Treatment Plant

During OMM, the raw influent and final effluent from the ATP will continue to be analyzed for arsenic daily when the ATP is operating.

Pumping Stations

During OMM, the groundwater samples will continue to be collected monthly from the six pumping stations (PS#1 to PS#6) and the two groundwater inspection holes and tested for aluminum, arsenic, cobalt, copper, lead, mercury, molybdenum, nickel, and zinc.

Groundwater Monitoring Program

During OMM, the remaining or replaced monitoring wells in the Industrial Area will continue to be sampled quarterly for the parameters listed in Section 6.2.1.

The groundwater at the outfall of the horizontal well conveyance pipe will be sampled monthly for the first year and quarterly thereafter, and analyzed for arsenic to monitor the effect of the GIWN. The analysis of other parameters may be re-evaluated in the future.

The water levels in the pressure relief wells will be monitored monthly for the first year and quarterly thereafter.

Groundwater seeps that may originate from the WCA will be analyzed monthly for arsenic and metals, and mitigation measures implemented if the water is contaminated.

Surface Water Monitoring Network

The 12 sampling stations listed in Table 6.2 will continue to be sampled weekly/monthly/quarterly and analyzed for the parameters listed in Section 6.2.1. The Moira River at Highway 7 will continue to be analyzed for arsenic with a 28-day sampler.

6.3 Biomonitoring

Biomonitoring will be undertaken in areas where natural environmental restoration measures are planned. This includes the revegetation of the west Moira River bank, and the capped and covered areas within the Industrial Area. The biomonitoring program will be undertaken during the first growing season following the construction of each remediated area, and annually thereafter for a total of five years. Biomonitoring will then be conducted once every five years over a twenty-year period, and then every ten years thereafter.

Visual inspections will also be conducted for the remedial work proposed along the west bank of the Moira River. These inspections will help to ensure that stream bank stability is not compromised and that the restoration measures implemented, including the installation of any bioengineering structures (e.g. root wads, fascines), are functioning as designed.

Qualified field personnel will evaluate the success of herbaceous vegetation (e.g. grasses, wildflowers, etc.) seeding and woody plantings in the capped areas. Plant health/condition will be monitored and woody-planted materials, such as shrubs and trees that are determined to be inadequate or dead will be replaced. Native colonizing species of shrubs and trees that germinate and grow in these areas will also be documented.

To further support the goals and objectives of the Industrial Area Closure Plan, the monitoring program may include the collection of plants (leaves and/or stems) from the capped and covered areas during the growing season and prior to senescence. The concentration of arsenic and metals of concern in these plant tissue samples could be chemically determined. Trends could be identified and comparisons to benchmark, toxicological and site data could be conducted to ensure that the goals of the Industrial Area Closure Plan are being met.

Wildlife use, including direct sightings or signs such as tracks and scat in the Industrial Area, should be documented and recorded on a site map, as one of the goals of the Industrial Area Closure Plan is to improve the quality and increase the quantity of wildlife habitat. Wildlife observations could be documented by qualified field personnel while undertaking the other investigations and thus, would be completed with the same frequency and over the same period of time.

6.4 Site Management

It is anticipated that the proposed rehabilitation alternative will achieve the expected conditions and uses in the long-term. As part of a long-term site management program, it is anticipated that the following measures will be implemented or maintained:

- Fencing exists on the perimeter of the Deloro Mine Site and access is restricted to authorized personnel
- Signage exists on the perimeter fence as well as at the north and south approaches along the Moira River
- The MOE will retain ownership and control of the site for the foreseeable future
- Site conditions will be registered on title at the conclusion of the cleanup coincident with the issuance of a Record of Site Condition (RSC)

The mitigation measures outlined in Section 7 will be addressed in the event that design malfunctions and/or accidents occur.

7. Malfunctions, Accidents, and Mitigation Measures

During the implementation and operation of the rehabilitative measures at the site, there is a potential that malfunctions (e.g. in design, construction, or commissioning) or accidents (e.g. due to acts of nature) could occur. These malfunctions and accidents can adversely affect remediation activities, and OMM, resulting in delays or costly mitigation measures. These events must be considered and mitigation measures must be developed to ensure environmental impacts are minimal and acceptable.

Table 7.1 identifies mitigation measures for potential malfunctions and accidents that have a reasonable probability of occurring at the site during three time frames:

- Short-term: Preparation activities
- Mid-term: Remediation activities
- Long-term: OMM activities

TABLE 7.1
MALFUNCTIONS, ACCIDENTS AND MITIGATION MEASURES IN THE INDUSTRIAL AREA

Malfunction (M) or Accident (A)	Mitigation Measures
Short-term: Preparation Activities	
M/A – Perpetual disruptive forces (MNDM, 1995)	The recommended alternative for rehabilitation of the Industrial Area incorporates measures to mitigate perpetual disruptive forces.
A – Spill of contaminated soil, ATP related chemicals, fuel for equipment and vehicles	Contractors, ATP operators and other site personnel should be trained to respond to spills. Spill would be isolated and transferred to WCA or to an acceptable waste receiver if spill occurs offsite.
Mid-term: Remediation Activities	
M/A – Perpetual disruptive forces (MNDM, 1995)	The recommended alternative for rehabilitation of the Industrial Area incorporates measures to mitigate perpetual disruptive forces.
A – Spill of contaminated soil, ATP related chemicals, fuel for equipment and vehicles	Contractors, ATP operators and other site personnel should be trained to respond to spills. Spill would be isolated and transferred to WCA or to an acceptable waste receiver if spill occurs offsite.
M/A – During excavation and consolidation activities, severe storm events could expose contaminants or transport contaminants via wind or stormwater	Contain stormwater and make sure that sediment controls are in place. Implement contingency plan to dewater ponded water in excavations. Sedimentation catchments will be in place during construction activities. Excavation should be staged such that contaminated sediments cannot be washed into clean areas. These design measures should be sufficient during normal storm events. Sequence work to avoid areas subject to erosion during severe storm events.

TABLE 7.1
MALFUNCTIONS, ACCIDENTS AND MITIGATION MEASURES IN THE INDUSTRIAL AREA

Malfunction (M) or Accident (A)	Mitigation Measures
M/A – During simple earth (clay) cap/engineered cover placement, soils, and vegetation could wash away	Straw blown onto sloped areas that are freshly planted, and planting with annual rye or wheat will help stabilize the soil. If soils are washed away, then replace the soil and replant.
A – Damage to existing groundwater collection system during construction activities	Piping may require rerouting and a temporary shutdown during waste consolidation and cap/cover construction activities. As groundwater control is essential to limiting the migration of arsenic to the Moira River, system downtime will be minimized.
Long-term: Operation, Maintenance, and Monitoring Activities	
M/A – Perpetual disruptive forces (MNDM, 1995)	The recommended alternative for rehabilitation of the Industrial Area incorporates measures to mitigate perpetual disruptive forces.
A – Spill of ATP related chemicals, GIWN cleaning chemicals, fuel for construction equipment/vehicles	ATP operators and other site personnel should be trained to respond to spills. Spill would be isolated and transferred to an acceptable waste receiver.
M – Breach of consolidated waste cover or simple earth (clay) cap	Although the thickness of the cover and simple earth (clay) cap are designed to prevent penetration from tree roots and burrowing animals, there is a remote possibility that this can happen. Ongoing OMM program will identify need for repairs to covers and caps. The site OMM manual will provide Simple Earth (Clay) Cap/Cover Repair procedures and protocols.
M – Riverbank erosion	Ongoing monitoring program will identify need for repairs to riverbank. The site OMM manual will provide riverbank repair procedures and protocols.
M – Drainage ditches and culverts fill with sediment and debris or require repairs	Ongoing monitoring program will identify need for cleaning or repairing drainage ditches and culverts. The site OMM manual will provide drainage ditch and culvert cleaning and repair procedures and protocols.
M – Tree mortality due to soil conditions, contaminants, rodents, etc.	Install raptor perches to encourage hawks and owls to prey on rodents. Monitor routinely the health of the trees. Mulch trees and keep grass mowed to reduce potential for rodent damage. If mortality occurs, determine cause of mortality (soil conditions, contaminants, rodents) and rectify then replace trees.
M – Leachate transfer pump failure	Use standby pump, routine monitoring of pump performance.
M – Leachate transfer pump capacity insufficient	Purchase appropriate pump and replace original pump.
M – Piping failure	Install auto shutoff that is triggered if back pressure is too low, and routinely monitor the pipe integrity.
M – Piping frozen	Shut down pump and thaw line. Check heat tracing integrity, and routinely monitor that the collected water is flowing.
M – Irrigation system not functioning	Troubleshoot and repair and restart or, if problem cannot be easily remedied, use a watering truck.
M – Electrical short circuiting in pump control panel	Troubleshoot and repair. If due to rain/moisture, ensure waterproof features are in place.

TABLE 7.1
MALFUNCTIONS, ACCIDENTS AND MITIGATION MEASURES IN THE INDUSTRIAL AREA

Malfunction (M) or Accident (A)	Mitigation Measures
M – Cover failure or riverbank erosion due to flooding	Although the majority of the cover is approximately 5 m above the floodplain of the 100-year flood, site vegetation will require a number of years before becoming well established. Therefore, it is possible that a flood could compromise the integrity of the various caps/covers in the Industrial Area and lead to the release of contained wastes and soils. Any damaged areas during such an event would be identified and rectified using defined maintenance procedures.
A – Seismic occurrences	Design long-term structures at the Deloro site to the appropriate Seismic Zone. The probability of an earthquake of sufficient magnitude to breach the cover of the WCA is very small given the stability of the region (Zone 1, low risk of earthquake). Any damaged areas during such an event would be identified and rectified using defined maintenance procedures.

Notes: Perpetual disruptive forces are defined in MNDM (1995) to include wind erosion; water erosion due to flooding, sheeting, rilling, and gulleying; sedimentation and debris accumulation; annual ice accumulation; seasonal frost penetration; soil restructuring; and physical and chemical weathering. Biological activities include root penetration, burrowing, intrusion, and actions by animals and man.

8. Expected Post-Closure Conditions and Uses

This section provides an assessment and description of the expected conditions and uses following closure activities.

8.1 Land Use

The final intended use of the site will be specified as a component of the federal EA. It is anticipated that access to the site will continue to be restricted (as described in Section 3.1) and the fence that currently surrounds the site will be maintained for the foreseeable future.

8.2 Topography

In general, the revised topography in the Industrial Area will be heavily dependent on:

- The amount of HLW identified and excavated from areas
- The final grade of the land, that will be suitable for stormwater runoff yet minimize stormwater erosion
- The thickness of the engineered cover or simple earth (clay) caps applied to the area
- The amount of waste consolidated around the equalization pond

It is anticipated that the ground surface of the consolidated wastes and engineered cover will rise to a maximum elevation of approximately 205 masl; the approximate grade of the Village of Deloro. The mound will be approximately 5 m below the localized topographic high points at the north end of the Industrial Area.

Tree cover between the Village and the WCA will reduce visual impacts to Deloro residents.

Figures 3-10 to 3-12 show the cross-sections of the anticipated topography of the Industrial Area following the completion of the site rehabilitation program.

8.3 Water Resources

It is anticipated that the implementation of the recommended rehabilitation alternative for the Industrial Area will result in a marked improvement to the Moira River water quality, and be supportive of the overall closure objective of a 90 percent reduction in arsenic discharge to the Moira River to achieve PWQOs at the intersection of the Moira River and Highway 7 (CG&S, 1998).

8.4 Plant and Animal Life

As noted in Section 2.1.2, the post-closure risks to ecological receptors from the draft SLERA are not conclusive given information that is currently available. Additional site information is being collected and further risk evaluation is underway.

9. Approval Requirements

The primary site-wide regulatory approvals that must be applied for and issued by the appropriate government agencies are outlined in this section of the Closure Plan.

9.1 Site-Specific Risk Assessment

SSRA is the remedial approach selected from the options available in the GUCSO (MOE, 1997). There are a number of steps to approval of an SSRA to ensure that public health and the environment are protected. First, an SSRA is reviewed by an independent third party peer reviewer, qualified and experienced in conducting SSRAs. Once the peer reviewer's comments have been incorporated, the SSRA is submitted to the Standards Development Branch (SDB) of the MOE, which undertakes a review of both technical and policy issues. Other prerequisites for acceptance of the SSRA include community-based public communication and dialogue with the municipality regarding the SSRA. Once these steps have been completed, the cleanup can proceed.

As confirmation that the actual cleanup is completed according to the SSRA, a Record of Site Condition (RSC) will be prepared and filed to document the cleanup. The RSC is completed jointly by the proponent, MOE, as well as the consultant overseeing the cleanup. The SSRA is a Level 2 Risk Management involving the use of engineered controls (e.g. engineered covers, groundwater pumping/treatment systems). A Level 2 Risk Management requires Registration on Title for the property to document the conditions of the land in the public domain. Registration on Title will be accomplished through filing a Certificate of Prohibition.

As a result of the different land ownership between the Deloro Mine Site and the Young's Creek Area south of Highway 7, a separate draft SSRA report has been prepared for each of these two land parcels following the process described in this section.

The current process for completing SSRAs, outlined above, was developed in 1997 and has been in place since that time. New legislation has been passed that is anticipated to modify this process once the enabling regulations are finalized. The new legislation, the *Brownfield Law Statutes Amendment Act*, received Royal Assent on November 21, 2001 and the public comment period for the regulations ended on April 29, 2003. Final regulations, which are expected to be released through 2003, may change the SSRA process from a guideline-driven to a regulatory-driven process. The draft regulations do not suggest significant change in the technical approach to SSRAs, but they do indicate some changes in the administrative aspects. The Deloro Mine Site SSRA will be adapted, if needed, to meet the new regulatory requirements.

9.2 MOE Authorizations

Under the *Environmental Protection Act* (EPA) and the *Ontario Water Resources Act* (OWRA), approval is required from the MOE for processes that emit to the environment or for waste management activities. The primary means of approval is through issuance of a Certificate of Approval (C of A) for air or water emissions or a Provisional Certificate of Approval (PC of A) for waste related activities. A Permit to Take Water (PTTW) is required for water extraction above 50,000 L/day. Generator Registration is required for ongoing waste generation, such as the ferric arsenate sludge, which is generated by the onsite ATP.

A number of MOE authorizations already exist at the Deloro Mine Site as a result of environmental mitigation actions implemented to date. This includes extraction and pumping of impacted groundwater, treatment of water in the ATP, discharge of the treated effluent and storage/dewatering of sludge from the treatment process. A listing of the MOE authorizations currently in place at the Deloro Mine Site is provided in Table 9.1.

The Closure Plans will result in changes to the currently authorized systems, plus the addition of new systems. Changes to the current systems will require modifications to the existing MOE authorizations, most likely through an amendment (i.e. C of A Amendment). New systems will require new authorizations to be developed.

Certificate of Approval – Sewage

Amendment to the existing C of A for the ATP, sludge storage lagoon, pumping stations, and forcemains may be required to accommodate modifications to these systems as a result of the Closure Plans.

Certificate of Approval – Air

There is no anticipated requirement for modification of the existing C of As or for new C of As as a result of the Closure Plans.

Permit to Take Water

The existing PTTW for the Tuttle Shaft pumping station will require amendment to account for installation of a permanent forcemain and the increase in pumping to a year-round operation. Other PTTWs for the other pumping stations may also require some modifications.

In the Industrial Area, a new PTTW will be required to authorize the construction and operation of a groundwater interceptor system at the western property line. Similarly, a new PTTW will be needed in the Tailings Area for groundwater pumping from wells located in the vicinity of the tailings dams.

Provisional Certificate of Approval – Waste Disposal

The site cleanup is following the SSRA process (outlined above) where existing residuals and by-products will be managed onsite through a Level 2 Risk Management involving isolation and containment. Although the legacy materials being managed have been in place for several decades and are not the result of ongoing waste production and many of the materials are the result of mining activities (e.g. mill tailings from a mine) that are exempt from Ontario's Waste Management Regulation, the MOE has committed to seeking a PC of A for the proposed waste management facilities under Part V of the EPA. The development of Closure Plans for the Deloro site has drawn on landfill design standards, as well as mine closure and other guidelines, as general guidance and best management practices to ensure that the site is engineered and maintained to be safe and secure for hundreds of years.

TABLE 9.1
EXISTING MOE AUTHORIZATIONS FOR THE DELORO MINE SITE

Authorization	Type	Number	Date	Description
Certificate of Approval	Sewage	4-036-82-006	28 Jul 1982	Collection/storage/ treatment system
Certificate of Approval	Air	8-4042-82-006	8 Sep 1982	Lime silo venting and fume hood exhaust
Certificate of Approval	Sewage	4-053-83-006	18 Jul 1983	Pumping station and forcemain
Provisional Certificate of Approval	Waste Disposal Site	A362106	6 Sep 1983	Temporary storage processed sludge
Permit	Permit to Take Water	85-P-4006	26 Apr 1985	Tuttle shaft and pumping station #5
Certificate of Approval	Sewage	4-041-85-006	25 Jul 1985	Sludge drying lagoon
Permit	Permit to Take Water	85-P-4038	16 Aug 1985	Moira River
Certificate of Approval	Sewage	4-067-85-006	16 Sep 1985	Manhole rehabilitation
Certificate of Approval	Air	8-4069-86-006	17 Nov 1986	Plant exhaust system
Certificate of Approval	Sewage	4-116-86-876	8 Jul 1987	Tuttle shaft pump and forcemain
Certificate of Approval	Sewage	4-0155-87-006	20 Nov 1987	Sludge testing lagoon
Certificate of Approval	Air	8-4120-88-006	12 Dec 1988	Lab equipment exhaust
Generator Registration	Waste Streams	ONO199886	23 Jan 1989	Arsenic compounds and oils
Certificate of Approval	Air	8-4128-89-006	4 Dec 1989	Lab fume hood exhaust
Permit Amendment	Permit to Take Water	83-P-4010	6 Jun 1990	Pumping station #3
Permit Amendment	Permit to Take Water	82-P-4035	6 Jun 1990	Pumping stations #1, #2, and #4
Certificate of Approval Amendment	Industrial Sewage	4-041-85-006	27 Nov 1992	Sludge storage lagoon expansion
Permit Amendment	Permit to Take Water	85-P-4006	21 Feb 1996	Tuttle shaft and pumping station #5
Certificate of Approval Amendment	Industrial Sewage Works	4-036-82-006	20 Apr 2000	Decontamination facilities
Generator Re-registration (HWIN)	Waste Streams	ONO199886	Jan 2002	Ferric arsenate sludge
Provisional Certificate of Approval	Waste Disposal Site	2668-5DHJEW	30 Aug 2002	Temporary storage contaminated soil
Provisional Certificate of Approval Amendment	Waste Disposal Site	2668-5DHJEW	12 Nov 2002	Contingency plan

The Deloro Mine Site Cleanup Project is being carried out under an exemption to the provincial *Environmental Assessment Act* (EAA). Ontario Regulation 577/98 (O. Reg. 577/98) exempts the Deloro Mine Site Cleanup Project from a mandatory hearing under Part V of the EPA (sections 30 and 32).

9.3 Conservation Authority

Through the Fill, Construction and Alteration to Waterways Regulation, which is administered in support of Section 28 of the *Conservation Authorities Act* of Ontario, the Conservation Authority regulates and may prohibit work taking place within valley, river, stream and watercourse corridors as well as along lake waterfronts.

Fill regulations allow the Authority to prohibit or regulate the placing, excavation, grading or dumping of fill of any kind for projects such as pools, ponds, roads and driveways. These regulations are applied when, in the opinion of the Authority, the control of flooding, pollution, or the conservation of land within its jurisdiction may be affected by the placing or dumping of fill.

Construction regulations allow the Conservation Authority to regulate construction in or on a wetland or floodplain, or in any area susceptible to flooding during a regional storm. In this regulation, construction refers to new buildings, additions to existing buildings, stormwater outfalls, culverts, and bridges.

The alteration to waterways regulation allows the Conservation Authority to prohibit or regulate the straightening, changing, diverting, or interfering with the existing channel of a river, creek, stream, or watercourse.

Based on the remedial works that are proposed along the west bank of the Moira River (reconstruction) as well as within Young's Creek (sediment and soil removal and wetland rehabilitation), it is anticipated that a permit "To Construct, Place Fill, or Alter a Waterway" will be required from the Moira River Conservation Authority (MRCA) c/o Quinte Conservation (QC).

9.4 Ministry of Natural Resources

Of note within the Deloro Mine Site property and in the Young's Creek Offsite Area is a Provincially Significant Wetland (PSW), the Deloro Wetland Complex. The Deloro Wetland Complex, including the area along Young's Creek south of Highway 7, was evaluated during the summer of 2000 using the 3rd Edition of the wetland evaluation manual (Snider's Ecological Services, 2000). The wetland received a total score of 688 and was evaluated as a Class 2 PSW.

The management of Ontario wetlands and lands adjacent to them is implemented through the *Wetlands Policy Statement,* which falls under the jurisdiction of the *Planning Act*. The MNR and the Minister of Municipal Affairs jointly issued the *Wetlands Policy Statement*. The policy requires that all planning jurisdictions protect PSWs such that development is not permitted in PSWs that are located within the Great Lakes—St. Lawrence Region. Development and alteration may be permitted on lands adjacent to PSWs only if it does not result in:

- Loss of wetland function
- Subsequent demand for future development that will negatively impact existing wetland functions
- Conflict with existing site-specific management practices
- Loss of wetland area

An Environmental Impact Study (EIS) would have to be prepared in order to permit development on these adjacent lands.

Consultation is required with the MNR, and possibly the Minister of Municipal Affairs, to determine whether any of the project components, such as construction of the Young's Creek Area onsite containment cell and dredging, constitutes wetland "development" and whether the project can be permitted. Also, the MNR would need to determine whether an EIS would need to be completed.

The MNR is also responsible for issuing Work Permits under the authority and provisions of several different Provincial Acts. If the project is allowed to proceed, the Provincial Acts that apply to this project would have to be determined in consultation with the MNR. The following Provincial Acts and their regulations are considered in the application for a Work Permit.

Forest Fire Prevention Act: The MNR administers this Act. A Work Permit is required to authorize any work on Crown land, and to ensure that adequate forest fire precautions and equipment are in place.

Lakes and Rivers Improvement Act: The purpose of this Act is to manage the use of the lakes and rivers in Ontario, and to regulate improvements to them. The Act provides for the preservation of public rights in or over water; protection of the interests of riparian owners; management of fish, wildlife, and other natural resources dependent on such waters; preservation of natural amenities; and suitability of the location and nature of improvements. The *Lakes and Rivers Improvement Act* gives the MNR the mandate to manage water-related activities, particularly in the areas outside the jurisdiction of Conservation Authorities.

Public Lands Act: This Act, which is administered by the MNR, authorizes the construction of roads on Crown lands, sets out Crown cost-sharing of company roads, limitations on liability and tenure for private forest roads and camp areas, and defines the applicability of the *Highway Traffic Act* on access roads.

As part of the application for a Work Permit, each project proponent must complete and apply for "Parts" of the permit. The determination of which Parts (i.e. A through F) are applicable to the project is conducted in consultation with the MNR. The Parts that must be taken into consideration when applying for a Work Permit are briefly described below:

- *Part A*: Fire Prevention and Suppression/Logging Activities
- *Part B*: Mineral Exploration Activities
- *Part C*: Building Construction
- *Part D*: Application to do Work on Shore Lands
- *Part E*: Roads, Trails, or Water Crossings
- *Part F*: Works Within a Waterbody

Based on the work proposed at the Deloro Mine Site, a Work Permit will be required from the MNR. Several Parts to the application will have to be completed possibly including, but not limited to, Parts A, D, and F. It is anticipated that the MNR will include conditions pertaining to work in the PSW with those issued as part of the Work Permit.

9.5 Department of Fisheries and Oceans/ Canadian Coast Guard

9.5.1 Navigable Waters Protection Act (NWPA)

The purpose of the NWPA is to protect the public right to marine navigation, and to ensure unobstructed passage of vessels in Canadian waters. Any construction, modification, or repair of a work that will interfere with navigable waterways must be approved, or concurrence provided by the DFO, and is administered by the Canadian Coast Guard (CCG). The removal of obstructions to navigation, and the provision and maintenance of lights and markers required for safe navigation are also covered under this Act. Although the section of the Moira River that passes through the site has limited use for boating, many parts of the Moira River are navigable and the CCG should be consulted on the final cleanup plan for the site.

9.5.2 Fisheries Act

The federal Minister of Fisheries and Oceans has the legislative responsibility for the administration and enforcement of the federal *Fisheries Act*. The *Fisheries Act* protects and conserves fish and fish habitats, and has the power to deal with damage to fish habitat, destruction of fish, obstruction of fish passage, necessary flow requirements for fish, and the control of deleterious substances. Section 35(1) of the federal *Fisheries Act* states that "no person shall carry on any work or undertaking that results in the harmful alteration, disruption, or destruction (HADD) of fish habitat". Any proposed works and activities that are likely to alter or damage fish habitat must be reviewed and authorized by the DFO. The Conservation Authorities have agreements with the DFO in the evaluation and processing of applications, and therefore would also have to be consulted.

It is important to note that DFO has also developed a Policy for the Management of Fish Habitat, which includes a No Net Loss guiding principle. This principle is applied to any proposed development that would result in a loss of productive fish habitat. The regulatory agency would review the measures to determine if they meet not only the No Net Loss of fish habitat, but also the DFO's long-term policy objective of achieving an overall net gain of the productive capacity of fish habitats. Therefore, works requiring an authorization from the DFO typically include a Fisheries Compensation Plan, which describes the measures taken to realize an overall net gain in the productive capacity of fish habitats as a result of the project.

A section of the west bank of the Moira River in the Industrial Area will be reconstructed, and a significant amount of work is proposed within Young's Creek including the excavation of contaminated sediments/soils and wetland rehabilitation. As this will affect fish habitat, a Fisheries Act authorization will be required, and a Fisheries Compensation Plan may have to be prepared. In addition, application for a blasting permit may be required to address "destruction of fish by any other means" (under the *Fisheries Act*), since a portion of the onsite containment cell will be located in Young's Creek.

9.6 Environmental Assessment and CNSC Licensing

The NSCA mandates the CNSC to regulate all aspects of the nuclear industry in Canada, including the management and isolation of nuclear wastes. Paragraph 26 of the NSCA states that:

> "Subject to the regulations, no person shall, except in accordance with a licence,…possess…manage, store or dispose of a nuclear substance. . ."

It is with respect to this paragraph that the MOE seeks to obtain a licence to manage and store, at various locations on the Deloro Mine Site, the low-level radioactive wastes present on the site. Conceptual waste isolation scenarios are presented in Section 3.4 of this and other Closure Plans for low-level radioactive (and non-radioactive) materials.

CNSC's authorization of the project would be provided through the issuance of a Waste Nuclear Substance Licence (WNSL) for the possession, management and storage of nuclear substances, pursuant to subsection 24(2) of the NSCA.

As previously noted, because nuclear waste management and storage is a physical activity listed in the "Inclusion List Regulation" of the CEAA, the proposed project is subject to the federal EA process. Therefore, the licencing and the federal EA processes are closely linked, as explained below.

The screening level EA process being followed for this project is outlined in Section 2.3. At the completion of the EA study, the proponent must summarize the process and the results of the EA into a report that is submitted to the RA for its review. Once the RA is satisfied that the EA has met the initial scope, the report is then submitted to the members of the CNSC for its approval. A hearing in which the proponent presents the project and where the public is invited to voice its concerns or support may be required.

Following the approval of the results of the EA by the CNSC, an application for a WNSL must be formally submitted by the proponent in accordance with the General Nuclear Safety and Control Regulations and Nuclear Substance and Radiation Devices Regulations of the NSCA. A WNSL is applicable, as opposed to a Class Ib Nuclear Facility Licence, because mainly chemical wastes are being managed with the presence of some low-level radioactive materials.

As part of the application for a WNSL, safety analyses must be conducted to ensure low-level radiation exposures to both workers and the public are acceptable during normal and abnormal conditions at the site.

Some applicable portions of the General Nuclear Safety and Control Regulations, which must be addressed in the application, are as follows:

> 3 (1) (*e*) the proposed measures to ensure compliance with the *Radiation Protection Regulations* and the *Nuclear Security Regulations*;
> (*f*) any proposed action level for the purpose of section 6 of the *Radiation Protection Regulations*;
> (*g*) the proposed measures to control access to the site of the activity to be licensed and the nuclear substance, prescribed equipment or prescribed information;
> (*h*) the proposed measures to prevent loss or illegal use, possession or removal of the nuclear substance, prescribed equipment

> or prescribed information;
> (*i*) a description and the results of any test, analysis or calculation performed to substantiate the information included in the application;
> (*j*) the name, quantity, form, origin and volume of any radioactive waste or hazardous waste that may result from the activity to be licensed, including waste that may be stored, managed, processed or disposed of at the site of the activity to be licensed, and the proposed method for managing and disposing of that waste;

Some applicable sections of the Nuclear Substance and Radiation Devices Regulations are as follows:

> **3.** (1) An application for a licence in respect of a nuclear substance or a radiation device, other than a licence to service a radiation device, shall contain the following information in addition to the information required by section 3 of the *General Nuclear Safety and Control Regulations*:
> (*a*) the methods, procedures and equipment that will be used to carry on the activity to be licensed;
> (*b*) the methods, procedures and equipment that will be used while carrying on the activity to be licensed, or during and following an accident, to
> (i) monitor the release of any radioactive nuclear substance from the site of the activity to be licensed,
> (ii) detect the presence of and record the radiation dose rate and quantity in becquerels of radioactive nuclear substances at the site of the activity to be licensed,
> (iii) limit the spread of radioactive contamination within and from the site of the activity to be licensed, and
> (iv) decontaminate any person, site or equipment contaminated as a result of the activity to be licensed;
> (*c*) a description of the circumstances in which the decontamination referred to in subparagraph (*b*)(iv) will be carried out;

Following submission of the application and any clarifications and/or additional materials required by CNSC staff, a draft licence is then prepared by CNSC staff, discussed with the proponent and ultimately presented to the members of the CNSC for approval. A hearing in which the proponent presents its application and where the public is invited to voice its concerns or support, may be required. Upon acceptance, a WNSL is issued and remedial work can begin under the conditions of the Licence.

9.7 Mining Act

The regulatory considerations relevant to the Deloro project were examined early in the project and have been refined as the project has progressed. The document entitled *Deloro Mine Rehabilitation Project – Development of Closure Criteria, Final Report* (CG&S, October 1998) summarized the application of the *Mining Act* to the Deloro project. Even though the Crown (i.e. the Provincial Government) is exempt from the requirements of the *Mining Act,* the Closure Plans have been developed to satisfy in general the requirements of the document entitled *Rehabilitation of Mines, Guidelines for Proponents* (MNDM, 1995). MNDM has agreed to review the Closure Plans relative to accepted standards for closure and rehabilitation of mines in Ontario, although a specific approval will not be issued.

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APPENDIX A

REPORT ON MODELLING DELORO MINE INDUSTRIAL AREA REMEDIATION SCENARIOS

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1. Introduction

In 2003, CH2M HILL developed a groundwater flow model for the Deloro Mine Site (Deloro Mine Site Cleanup, Groundwater Flow Simulation [CH2M HILL, July 2003]). The model was developed using available information from borehole logs and test pits constructed at the mine site. The groundwater flow modelling simulated existing groundwater conditions in the Industrial Area. Groundwater levels in the monitoring wells and flows to the existing groundwater pumping stations were used as calibration data.

Several remediation scenarios for the Industrial Area were evaluated with the model, which incorporated an engineered composite cover with and without a geosynthetic clay liner (GCL) to minimize infiltration of precipitation through the waste into the groundwater. Although the addition of the GCL almost eliminated infiltration through the engineered cover, the groundwater levels did not change significantly from the scenario with the engineered cover without the GCL. As the engineered cover did not accomplish the objective of dewatering of the surficial deposits, several scenarios involving drains and pumping wells were also evaluated with the model.

A passive scenario is preferred over active pumping because it supports the site-wide closure objective of minimizing perpetual operation and maintenance. As such, a horizontal drain installed 2 m below the bedrock surface and extending from the north end of the engineered cover, south to the Moira River, was determined to be the preferred option, based on the 2003 modelling results. The modelling indicated that, if implemented, this option would dewater most of the overburden under the engineered cover. However, the modelling indicated that the overburden deposits under the southern part of the engineered cover, south of the east-west site access road, would not be completely dewatered by the drain. As a result, the modelling report recommended moving the waste and engineered cover to the north of the east-west site access road, to the area where dewatering of the overburden was determined to be more effective, based on the results of the modelling. (This has been addressed in Section 3.4.1 [see Figure 3-5] of the attached Industrial Area Closure Plan).

Evaluations undertaken subsequent to the completion of the 2003 modelling report indicated that constructing a drain 2 m below the bedrock surface would provide significant construction challenges. This is due to fluctuations in the elevation of the bedrock surface; the variable thickness of overburden above the bedrock (ranging from less than 1 m to more than 6 m along the proposed alignment of the drain);and the need for significant dewatering during construction. In addition, the available area is limited and may be insufficient to maintain stable side slopes of the drain in overburden during construction.

The previously developed model for the Deloro Mine Site was used as the basis for modelling a number of new potential groundwater diversion/control scenarios, as part of the remediation of the Industrial Area. The following sections of this report describe the technical approach for updating the model and summarize the modelling results for these new scenarios.

Conclusions and recommendations are also presented at the end of this report. An outline of follow-up work to allow the recommended scenario to be further developed is also included. This will reduce uncertainties in the predicted performance and allow Final Design of the groundwater interception system.

2. Technical Approach

2.1 Updating Model Setup

This section describes the updates/modifications to the original groundwater flow model undertaken as part of the current modelling exercise. For details on the setup and calibration of the original model, refer to CH2M HILL's 2003 modelling report referenced previously.

In the original modelling exercise completed in 2003, some of the available information on ground surface elevations and depths to bedrock at geotechnical boreholes drilled in the Industrial Area were not used (Reference: "Task 423C, Geotechnical Investigation of Subsurface Conditions for the Proposed Groundwater Cross-Flow Interceptor, Technical Memorandum, CH2M HILL, March 28, 2001"). In the 2001 report, elevation data for the ground surface and top of bedrock was derived from an air photo-generated contour map. This data was not used in the original modelling due to concerns about its accuracy. However, in the current modelling exercise, this data was used to update the model in the critical area of the equalization pond and the proposed groundwater interceptor system.

Data from the geotechnical boreholes in the above report were incorporated into the original ground and bedrock surface grid files and re-contoured on a 10-metre grid spacing. These new surfaces were subsequently imported into MODFLOW and the model re-run with the new layer configurations. Due to uncertainties in elevations, the interpolated ground and bedrock surface elevations should be viewed as approximate.

Model calibration was satisfactory (approximately 9.4 percent normalized root mean square error) with the new surface configurations.

In the original model, the preferred remediation scenario used an engineered composite cover without a geosynthetic clay liner (GCL) installed. The updated Industrial Area Closure Plan (*Deloro Mine Site Cleanup – Industrial Area Closure Plan, Final Report* [CH2M HILL, August 2004]) incorporated a GCL as part of the engineered cover in order to reduce the infiltration of precipitation through the waste and reduce leachate generation .

The model was updated to include the GCL as part of the engineered cover. To represent the effect of the GCL in the model, the overall infiltration through the cover was reduced to 1.54 mm/year as determined from the HELP modelling completed as part of the original model development.

As discussed previously, the results of modelling the shallow bedrock groundwater interceptor drain indicated that the southern part of the site under the proposed engineered cover could not be dewatered. The modelling report recommended moving the waste and engineered cover to the north of the east-west site access road. As a result, the southern limit of the engineered cover was moved northward to correspond to the northern edge of the road as shown on Figure 3-12 in the *Industrial Area Closure Plan, Draft Report* (CH2M HILL, March 2004). This revised waste area/cover configuration has been incorporated into the updated model.

In subsequent sections of the report, the updated groundwater flow model is referred to as the base model.

2.2 Modelling Approach

The various remediation scenarios were modelled as steady-state models. The results reflect the steady-state conditions that will prevail once the remedial elements of the scenario have been installed and have been in operation for a period of time. There will be significant transient effects once the remediation scenario has been implemented which will persist until the new groundwater level regime is achieved.

The modelling results were evaluated by comparing the predicted groundwater levels in the deeper overburden under the respective remediation scenario with those of the base model. In modelling the remediation scenarios, it was initially assumed that the primary objective of the remediation scenarios was to completely dewater the surficial deposits (overburden). In order to quickly determine from the modelling results if this criterion had been satisfied, the point of the deepest known bedrock surface elevation under the proposed engineered cover area was identified in the base model. This point is at row 198, column 57 of the model, under the equalization pond, and has been identified as Test Cell 1. The top of bedrock elevation in the model is 187.53 metres above sea level (masl) at this cell. The model-generated groundwater levels and saturated thickness in this cell was compared to this elevation. Saturated thickness maps of the surficial deposits were only generated if the head in the test cell was lower than the top of bedrock.

The hydraulic head in Layer 2 (deep overburden) at Test Cell 1 in the base model is 192.62 masl. This is 5.09 m above the bedrock surface. In some modelling scenarios, two other test cells in addition to Test Cell 1 were identified in Layer 2 in order to compare simulated water levels and saturated thickness with the elevation of the bedrock surface. These additional test cells are identified and evaluated in the appropriate remediation scenario.

Flows to the groundwater pumping stations were used to show the impact on flows to the pumping stations in the base model, and the effect of each respective remediation scenario, compared to existing site conditions. Less flow to the pumping stations was interpreted to represent a more effective remediation scenario. Once steady-state conditions with the best remediation scenario are achieved, the pumping stations may not need to operate. The comparisons were developed to demonstrate the relative effectiveness of the remediation scenarios.

The water budget for existing conditions, as given in the Deloro Mine Site Cleanup, Groundwater Flow Simulation (CH2M HILL, July 2003), shows the simulated flows to the pumping stations. Water budget zones were originally developed in the model as MODFLOW zone budget zones and are consistent throughout the following report. These simulated flows are duplicated in Table 1 for reference.

TABLE 1
WATER BUDGET ZONES FOR PUMPING STATIONS, EXISTING CONDITIONS

Zone	Pumping Station	Existing Conditions Flow (m^3/day)
Zone 3	PS3	112.7
Zone 7	PS1 and PS2	15.0
Zone 8	PS4	86.7
Zone 9	PS5	40.7

Groundwater pathline modelling was used to evaluate the origin of groundwater entering the wells or drains included in some of the scenarios and the relative effectiveness of the respective remediation scenario. The pathlines defined the capture zone of the well or drain, and provided a general indication of the proportion of contaminated versus uncontaminated water that would likely enter the well or drain.

The following sections of this report describe modelling results for a series of remediation scenarios with the updated groundwater flow model (i.e. base model).

3. Updated Model With Engineered Cover Including GCL (Base Model)

The piezometric surface for the updated model (base model) deeper overburden, Layer 2, is shown in Figure 1 (see Appendix A.1). This piezometric surface includes the influence of reduced recharge under the engineered cover with the GCL. This figure shows that groundwater flows from the northwest to southeast to the Moira River. Within the Industrial Area, the groundwater elevation within the deeper overburden ranges from approximately 197 masl to approximately 188 masl, indicating that a relatively steep horizontal hydraulic gradient exists beneath the Industrial Area.

The predicted groundwater flows to the pumping stations for the base model (engineered cover with GCL) are summarized in Table 2. This table shows that the engineered cover with the GCL is predicted to significantly reduce the flows to the pumping stations.

TABLE 2
PREDICTED PUMPING STATION FLOWS FOR BASE MODEL

Zone	Pumping Station	Existing Conditions Flow (m^3/day)	Predicted Base Model Flow (m^3/day)	Base Model Percent of Existing Conditions Flow
Zone 3	PS3	112.7	72.5	64.3
Zone 7	PS1 and PS2	15.0	3.0	20.0
Zone 8	PS4	86.7	38.3	44.2
Zone 9	PS5	40.7	18.1	44.5

4. Remediation Scenarios

Several different remediation scenarios were constructed and evaluated using the base model, which included the engineered cover with GCL. These include:

1. Base model with a perimeter drain with a maximum depth of 4.9 m around the north, west and south sides of the revised engineered cover footprint.
2. A grout curtain/impermeable wall extending 2 m into bedrock on the north, west and south sides of the engineered cover.
3. A grout curtain/impermeable wall extending 2 m into bedrock on the north and west sides of the engineered cover (referred to as the Partial Wall).
4. A (Partial Wall) grout curtain/impermeable wall to 2 m depth with the interceptor drain included with the same configuration as in Scenario 1.
5. A (Partial Wall) grout curtain/impermeable wall to 6 m depth with the interceptor drain included with the same configuration as in Scenario 1.
6. Deep interceptor wells on the north and west sides of the engineered cover installed to 30 m.
7. A (Partial Wall) grout curtain/impermeable wall to 2 m depth with the deep interceptor wells as in Scenario 6.
8. A horizontal well with 0.5 percent slope which mimics the shape of the engineered cover on the north and west sides and extends southward to the natural marsh approximately 175 m south of the site access road.
9. A horizontal well with 0.5 percent slope which extends north to the area west of the Tuttle Shaft with no east-west extensions.
10. Scenario 9 with (partial) grout curtain/impermeable wall to 2 m below bedrock surface.
11. A "level" horizontal well in the bedrock along the west side of the site, which extends from north of the Tuttle Shaft south to the east-west site access road. From there, a HDPE pipe conveys the water south to its outlet at the Moira River at the southwest property line.
12. Scenario 11 with eight vertical pressure relief wells spaced adjacent to the engineered cover which tap the deeper bedrock and flow to the horizontal well by artesian pressure. This horizontal well trends north-south and extends to the area just north of the Tuttle Shaft.

For the modelling scenarios, it was assumed that the horizontal wells would be constructed entirely in the bedrock.

4.1 Scenario 1: Base Model with a Perimeter Drain with Maximum Depth of 4.9 m Around the North, West, and South Sides of the Revised Engineered Cover Footprint

For Scenario 1, a perimeter drain with varying slopes was incorporated into the base model. In the model, this is represented as a drain where the elevation input for each drain cell controls the water levels outside the drain.

The drain was located just outside the limits of the engineered cover on the north, west and south sides. The maximum depth of the drain was 4.9 m below the ground surface (entirely within overburden). The location of the drain is shown in Figure 2 (see Appendix A.1).

The predicted steady state piezometric surface in Layer 2, deeper overburden, with the drain in operation is shown in Figure 2. Steady-state flow in the drain is 60.9 m^3/day. Modelling results for Scenario 1 indicate minimal lowering of the groundwater surface as a result of the drain's operation. The predicted hydraulic head in Test Cell 1 in Layer 2 is 192.34 masl, which is 0.28 m lower than the base model condition for this cell. The saturated thickness of the surficial deposits is 4.81 m in the test cell.

The predicted flows to the pumping stations under this scenario are summarized in Table 3. As shown in Table 3, the model predicts no significant reduction in flows under this scenario.

TABLE 3
PREDICTED PUMPING STATION FLOWS, SCENARIO 1

Zone	Pumping Station	Existing Conditions Flow (m^3/day)	Predicted Base Model Flow (m^3/day)	Base Model Percent of Existing Conditions Flow	Predicted Scenario 1 Flow (m^3/day)	Scenario 1 Percent of Existing Conditions Flow
Zone 3	PS3	112.7	72.5	64.3	73.0	64.8
Zone 7	PS1 and PS2	15.0	3.0	20.0	2.9	19.3
Zone 8	PS4	86.7	38.3	44.2	38.5	44.4
Zone 9	PS5	40.7	18.1	44.5	18.1	44.5

4.2 Scenario 2: A Grout Curtain/Impermeable Wall Extending 2 m into Bedrock on the North, West, and South Sides of the Engineered Cover

For Scenario 2, a grout curtain/impermeable wall extending 2 m into bedrock on the north, west and south sides of the engineered cover was incorporated into the base model. The grout curtain/impermeable wall combination was simulated using the wall package in MODFLOW. The location of the wall is shown on Figure 3 (see Appendix A.1).

The wall was assigned a permeability of 1 x 10^{-8} cm/sec and a thickness of 10 cm. In practice, the grout curtain will likely be thicker than 10 cm, especially in the bedrock where the grout will likely spread along fractures. The grout curtain was extended to the bottom of Layer 3, which is 2 m thick and is the top layer of the bedrock.

Figure 3 shows the predicted steady state piezometric surface in Layer 2, deeper overburden. Modelling results for Scenario 2 indicate installation of the wall results in minimal lowering of the groundwater surface.. The predicted hydraulic head in Test Cell 1 in Layer 2 is 192.03 masl, which represents a head drop of 0.59 m from the base model. The saturated thickness of the surficial deposits at the test cell is 4.5 m. It was determined that the south section of the wall, from where it intersects the east-west site access road, to the river, is detrimental since heads on the north side of the wall tend to be higher than heads on the south side of the wall.

The predicted flows to the pumping stations under this scenario are summarized in Table 4. These values are almost identical to flows in the base model with the exception of a 12.7 percent drop in PS3.

TABLE 4
PREDICTED PUMPING STATION FLOWS, SCENARIO 2

Zone	Pumping Station	Existing Conditions Flow (m^3/day)	Predicted Base Model Flow (m^3/day)	Base Model Percent of Existing Conditions Flow	Predicted Scenario 2 Flow (m^3/day)	Scenario 2 Percent of Existing Conditions Flow
Zone 3	PS3	112.7	72.5	64.3	63.3	56.2
Zone 7	PS1 and PS2	15.0	3.0	20.0	2.9	19.3
Zone 8	PS4	86.7	38.3	44.2	38.5	44.4
Zone 9	PS5	40.7	18.1	44.5	18.1	44.5

4.3 Scenario 3: A Grout Curtain/Impermeable Wall Extending 2 m into Bedrock on the North and West Sides of the Engineered Cover (referred to as the Partial Wall)

For Scenario 3, a grout curtain/impermeable wall extending 2 m into bedrock on the north and west sides of the engineered cover (referred to as the Partial Wall) was incorporated into the base model. This scenario is similar to Scenario 2, except that the southern extension of the wall in Scenario 2 (which bounds the south part of the engineered cover from just north of where the wall intersects the east-west site access road to the Moira River) has been removed.

Figure 4 (Appendix A.1) shows the extent of the wall/grout curtain and the predicted steady state piezometric surface in Layer 2, deeper overburden for Scenario 3. Modelling results for Scenario 3 indicate installation of the wall results in limited lowering of the groundwater surface. The predicted hydraulic head in Test Cell 1 in Layer 2 is 191.91 masl, which represents a head drop of 0.71 m from the base model. This gives a saturated thickness of 4.38 m in the surficial deposits in the test cell.

The predicted flows to the pumping stations under this scenario are summarized in Table 5. As shown in Table 5, the predicted flows are very similar to the base model.

TABLE 5
PREDICTED PUMPING STATION FLOWS, SCENARIO 3

Zone	Pumping Station	Existing Conditions Flow (m^3/day)	Predicted Base Model Flow (m^3/day)	Base Model Percent of Existing Conditions Flow	Predicted Scenario 3 Flow (m^3/day)	Scenario 3 Percent of Existing Conditions Flow
Zone 3	PS3	112.7	72.5	64.3	71.6	63.5
Zone 7	PS1 and PS2	15.0	3.0	20.0	2.8	18.7
Zone 8	PS4	86.7	38.3	44.2	38.5	44.4
Zone 9	PS5	40.7	18.1	44.5	18.1	44.5

4.4 Scenario 4: A (Partial Wall) Grout Curtain/Impermeable Wall to 2 m Depth with the Interceptor Drain Included with the Same Configuration as in Scenario 1

For Scenario 4, a grout curtain/impermeable wall extending 2 m into bedrock on the north and west sides of the engineered cover (Partial Wall), with an interceptor drain included with the same configuration as in Scenario 1, was incorporated into the base model. In this scenario, the wall has the same configuration as Scenario 3, but is extended south to the east-west site access road.

Figure 5 (see Appendix A.1) shows the extent of the wall/grout curtain, the interceptor drain and the predicted steady state piezometric surface in Layer 2, deeper overburden for Scenario 4. The predicted flow in the interceptor drain is 81.5 m^3/day. Modelling results for Scenario 4 indicate installation of the wall and drain result in limited lowering of the groundwater surface. The predicted hydraulic head in Test Cell 1 in Layer 2 is 191.76 masl, a drop of 0.86 m from the base model. The saturated thickness of the surficial deposits is 4.23 m in the test cell.

The predicted flows to the pumping stations under this scenario are summarized in Table 6. As shown in Table 6, the predicted flows are very similar to the base model.

TABLE 6
PREDICTED PUMPING STATION FLOWS, SCENARIO 4

Zone	Pumping Station	Existing Conditions Flow (m^3/day)	Predicted Base Model Flow (m^3/day)	Base Model Percent of Existing Conditions Flow	Predicted Scenario 4 Flow (m^3/day)	Scenario 4 Percent of Existing Conditions Flow
Zone 3	PS3	112.7	72.5	64.3	71.3	63.3
Zone 7	PS1 and PS2	15.0	3.0	20.0	2.7	18.0
Zone 8	PS4	86.7	38.3	44.2	38.5	44.4
Zone 9	PS5	40.7	18.1	44.5	18.1	44.5

4.5 Scenario 5: A (Partial Wall) Grout Curtain/Impermeable Wall to 6 m Depth with the Interceptor Drain Included with the Same Configuration as in Scenario 1

For Scenario 5, a grout curtain/impermeable wall extending 6 m into bedrock on the north and west sides of the engineered cover (Partial Wall), with an interceptor drain included with the same configuration as in Scenario 1, was incorporated into the base model. In this scenario, the wall has the same configuration as Scenario 4, but is installed deeper into the bedrock.

Figure 6 (see Appendix A.1) shows the extent of the wall/grout curtain, the interceptor drain and the predicted steady state piezometric surface in Layer 2, deeper overburden, for Scenario 5. The predicted flow in the perimeter interceptor drain is 86.2 m^3/day. Modelling results for Scenario 5 indicate installation of the wall and drain result in limited lowering of the groundwater surface. The predicted hydraulic head in Test Cell 1 in Layer 2 is 191.87 masl. This represents a decline of 0.75 m from the base model. The saturated thickness in the test cell is 4.34 m.

The predicted flows to the pumping stations under this scenario are summarized in Table 7. As shown in Table 7, there is a 13.8 percent decline in the flow to PS3, but the other flows are similar to the base model.

TABLE 7
PREDICTED PUMPING STATION FLOWS, SCENARIO 5

Zone	Pumping Station	Existing Conditions Flow (m^3/day)	Predicted Base Model Flow (m^3/day)	Base Model Percent of Existing Conditions Flow	Predicted Scenario 5 Flow (m^3/day)	Scenario 5 Percent of Existing Conditions Flow
Zone 3	PS3	112.7	72.5	64.3	62.5	55.5
Zone 7	PS1 and PS2	15.0	3.0	20.0	2.9	19.3
Zone 8	PS4	86.7	38.3	44.2	38.5	44.4
Zone 9	PS5	40.7	18.1	44.5	18.1	44.5

It is apparent from the modelling of Scenarios 1 to 5 that a grout curtain/wall by itself, or with a relatively shallow perimeter drain, is not sufficient to achieve dewatering of the surficial deposits.

4.6 Scenario 6: Deep Interceptor Wells on the North and West Sides of the Engineered Cover Installed to 30 m

For Scenario 6, wells were input into the base model and the number of wells and their pumping rates were varied until the piezometric surface of the deeper overburden under the engineered cover was lower than the bedrock surface. Three wells were required, one on the northeast side, one on the northwest corner of the engineered cover, and the third west of the equalization pond. The locations of the wells are shown in Figure 7 (see Appendix A.1). Pumping rates of the wells were 100, 150, and 450 m^3/day, respectively.

For this scenario, two additional test cells were added in the analysis in order to compare the hydraulic heads with the top of bedrock. Test Cell 2 is on the southwest edge of the equalization pond and Test Cell 3 is half way between the northern edge of the equalization pond and the primary treatment building.

Figure 7 shows the predicted steady state piezometric surface in Layer 2, deeper overburden, for Scenario 6. The predicted hydraulic head in Test Cell 1 in Layer 2 is 187.51 masl, which is 2 cm below the bedrock surface in the cell. The predicted hydraulic head at Test Cell 2 is 187.87 masl and the top of bedrock is 187.79 masl giving a saturated thickness of 8 cm. The predicted hydraulic head in Test Cell 3 is 188.58 masl and the top of bedrock is 188.42 masl, resulting in a saturated thickness in this area of 16 cm.

Figure 8 (see Appendix A.1) shows the predicted distribution of saturated thickness of the surficial deposits. With this configuration of wells pumping, most of the surficial deposits below the engineered cover would be dewatered. Given the uncertainty in obtaining accurate elevations of the top of bedrock, these predicted values of saturated thickness should be regarded with caution. There is a strip of overburden on the west bank of the Moira River that remains saturated under this remediation scenario. This strip of saturated overburden is present in all the remediation scenarios where complete dewatering of the overburden is obtained. Therefore, any leachable waste in this area has to be excavated and moved westward. The eastern limit of the proposed engineered cover will also have to be moved westward to correspond with the zero saturated thickness line.

Changing the depths of the wells to 15 m in the model had no effect on the resultant hydraulic heads. This is because the model is an equivalent porous media model and the deep bedrock is represented as one layer.

The predicted flows to the pumping stations under this scenario are summarized in Table 8. As shown in Table 8, there is a significant reduction in flow to all of the pumping stations compared to the base model. The pumping wells for PS4 and PS5 were made inactive in the model (no pumping) after it was determined that the overburden was dewatered in the area of these wells. The table reflects no pumping from these wells.

TABLE 8
PREDICTED PUMPING STATION FLOWS, SCENARIO 6

Zone	Pumping Station	Existing Conditions Flow (m^3/day)	Predicted Base Model Flow (m^3/day)	Base Model Percent of Existing Conditions Flow	Predicted Scenario 6 Flow (m^3/day)	Scenario 6 Percent of Existing Conditions Flow
Zone 3	PS3	112.7	72.5	64.3	52.7	46.8
Zone 7	PS1 and PS2	15.0	3.0	20.0	1.3	8.7
Zone 8	PS4	86.7	38.3	44.2	0	0
Zone 9	PS5	40.7	18.1	44.5	0	0

Reverse particle tracking was carried out to determine the origin of the groundwater entering the interceptor wells. The predicted reverse groundwater flow pathlines in the deeper overburden are shown in Figure 7. It is apparent from this figure that most of the groundwater captured by these wells originates from the west and north of the Industrial Area. A few pathlines cross the area of the engineered cover in the shallow and deep bedrock. The results of the particle tracking indicate that the groundwater pumped by the wells should be relatively uncontaminated by the wastes in the Industrial Area.

4.7 Scenario 7: A (Partial Wall) Grout Curtain/Impermeable Wall to 2 m Depth with the Deep Interceptor Wells as in Scenario 6

For Scenario 7, three pumping wells were used in the base model at the same locations as in Scenario 6. This scenario also included a grout curtain/impermeable wall (Partial Wall) to 2 m depth in the bedrock, in the same configuration as Scenario 4. Figure 9 (see Appendix A.1) shows the locations of the interceptor wells and grout curtain/wall. The pumping rate for the well just west of the equalization pond was reduced to 425 m^3/day.

Figure 9 shows the predicted steady state piezometric surface for Layer 3, the top of the bedrock, for Scenario 7. The predicted hydraulic head in Test Cell 1 in Layer 2 is 187.43 masl which is 10 cm below the bedrock surface in this cell. The predicted hydraulic head in Test Cell 2 is 187.64 masl, which is 15 cm below the bedrock surface. The hydraulic head in Test Cell 3 is 188.05 masl which is 37 cm below the bedrock surface. Thus, the difference in water levels between Scenario 6 and Scenario 7 for Test Cells 1, 2, and 3 is 8, 23, and 53 cm lower, respectively, for Scenario 7.

The modelling indicated that a strip of overburden along the west bank of the Moira River would remain saturated under this remediation scenario. Therefore, if this scenario is implemented, any leachable waste in this area that is in contact with the groundwater, should be excavated and moved westward. The eastern limit of the proposed engineered cover should also be moved westward to correspond with the zero saturated thickness line.

The predicted flows to the pumping stations under this scenario are summarized in Table 9. As shown in Table 9, there is a significant reduction in flow to all of the pumping stations compared to the base model. Flow to PS3 is slightly higher in this scenario than in Scenario 6. The pumping wells for PS4 and PS5 were made inactive in the model (no pumping) after it was determined that the overburden was dewatered in the area of these wells. The table reflects no pumping from these wells.

TABLE 9
PREDICTED PUMPING STATION FLOWS, SCENARIO 7

Zone	Pumping Station	Existing Conditions Flow (m^3/day)	Predicted Base Model Flow (m^3/day)	Base Model Percent of Existing Conditions Flow	Predicted Scenario 7 Flow (m^3/day)	Scenario 7 Percent of Existing Conditions Flow
Zone 3	PS3	112.7	72.5	64.3	58.3	51.7
Zone 7	PS1 and PS2	15.0	3.0	20.0	1.2	8.0
Zone 8	PS4	86.7	38.3	44.2	0	0
Zone 9	PS5	40.7	18.1	44.5	0	0

Reverse particle tracking was carried out for this scenario to determine the source of groundwater for the interceptor wells. Figure 9 shows the predicted reverse groundwater flow pathlines in the top of bedrock. It is apparent from this figure that the majority of groundwater flow to the interceptor wells originates from the north and west of the Industrial Area. Only a few pathlines cross under the engineered cover in the shallow bedrock indicating that the groundwater pumped by the wells should be relatively uncontaminated by the wastes in the Industrial Area.

4.8 Scenario 8: Horizontal Well with 0.5 Percent Slope Which Mimics the Shape of the Engineered Cover on the North and West Sides and Extends Southward to the Natural Marsh Approximately 175 m South of the Site Access Road

For Scenario 8, a horizontal well was incorporated into the base model in the bedrock. Initially, it was decided to model the horizontal well (drain) with approximately the same layout as in the original modelling completed in 2003 (deep interceptor trench) to evaluate the similarities between the two results. The drain in the original model was set at a varying elevation which was keyed to the bedrock surface, at a depth of 2 m below the bedrock surface. In some areas this resulted in a very deep drain.

For this scenario, the drain was placed in the same position along the northern edge of the engineered cover, but was moved west of New Westerly Creek on the west side of the engineered cover area (Figure 10 [see Appendix A.1]). A drain slope of 0.5 percent was used and the highest elevation of the drain, in this case simulating a horizontally drilled "well", was initially at the northeast corner of the engineered cover near borehole GA12-1.

Several simulations were required to determine the optimum elevation of the drain. In order to dewater the surficial deposits, the elevation of the drain in the same model row as Test Cell 1 had to be 184.21 masl. The model ground surface in this drain cell is at 200.7 masl, while the top of bedrock is at 187.3 masl.

The modelling results also indicated that the drain needed to be extended on the northeast side of the engineered cover in a direction southeast to the vicinity of borehole GR4-1, in order to achieve sufficient lowering of groundwater levels (Figure 10). The elevation of the drain near GR4-1 is 187.08 masl. The drain slope of 0.5 percent was maintained for this segment of the drain. The end of the drain, near GR4-1, is the drain's highest elevation.

The drain extends southward to the natural marsh approximately 175 m south of the site access road. The drain's elevation where it ends at the marsh is 182.8 masl, which is 6.0 m below the ground surface. Due to this elevation difference, the water would have to be pumped to the river at this location. The modelling results indicate that a horizontal well could be used, but the elevation of the well would have to be 184.21 masl or less to achieve dewatering of the surficial deposits.

Figure 10 shows the predicted steady state piezometric surface for Layer 3, the top of the bedrock, for Scenario 8. The predicted flow in the horizontal well is 1,557.6 m^3/day. The predicted hydraulic head in Test Cell 1 in Layer 2 is 187.43 m, which is 10 cm below the bedrock surface. The predicted hydraulic heads in Test Cells 2 and 3 are 0.84 and 1.12 m below the bedrock surface, respectively.

The modelling indicated that a strip of overburden along the west bank of the Moira River would remain saturated under this remediation scenario. Therefore, if this scenario is implemented, any leachable waste in this area that is in contact with the groundwater, should be excavated and moved westward. The eastern limit of the proposed engineered cover should also be moved westward to correspond with the zero saturated thickness line.

The predicted flows to the pumping stations under this scenario are summarized in Table 10. As shown in Table 10, there is a significant reduction in flow to all of the pumping stations compared to the base model. The pumping wells for PS4 and PS5 were made inactive in the model (no pumping) after it was determined that the overburden was dewatered in the area of these wells. The table reflects no pumping from these wells.

TABLE 10
PREDICTED PUMPING STATION FLOWS, SCENARIO 8

Zone	Pumping Station	Existing Conditions Flow (m^3/day)	Predicted Base Model Flow (m^3/day)	Base Model Percent of Existing Conditions Flow	Predicted Scenario 8 Flow (m^3/day)	Scenario 8 Percent of Existing Conditions Flow
Zone 3	PS3	112.7	72.5	64.3	43.1	38.2
Zone 7	PS1 and PS2	15.0	3.0	20.0	0.6	4.0
Zone 8	PS4	86.7	38.3	44.2	0	0
Zone 9	PS5	40.7	18.1	44.5	0	0

Reverse particle tracking was carried out for this scenario with particles placed on both sides of the drain and tracked backward to their point of origin. Figure 10 shows the predicted reverse groundwater flow pathlines in Layer 3, the top of the bedrock. As shown in Figure 10, there are few pathlines in the top of the bedrock. There are two groups of flow lines which flow in two directions as influenced by the horizontal well.

Figure 11 (see Appendix A.1) shows the pathlines in the deeper bedrock only (Layer 4). The majority of the pathlines are in the deeper bedrock. Pathlines from the shallow bedrock connect to those in the deeper bedrock. Therefore, if there is some degree of contamination in the shallow bedrock under the engineered cover, it could enter the horizontal well. However, the majority of groundwater flowing to the horizontal well originates from the west and north of the site and so is presumably uncontaminated.

As the overburden is dewatered under the engineered cover, there is no groundwater flow, and therefore, no pathlines in both overburden layers.

4.9 Scenario 9: Horizontal Well with 0.5 Percent Slope Which Extends North to the Area West of the Tuttle Shaft with no East-West Extensions

For Scenario 9, the east-west extension of the horizontal well (drain) just north of the engineered cover that was used in Scenario 8 was removed, and the drain was extended north 196 m to just north of the Tuttle Shaft (Figure 12 [see Appendix A.1]). The elevation of the drain is 186.35 masl at the end of its northern extension.

Figure 12 shows the predicted steady state piezometric surface for Layer 3, the top of the bedrock, for Scenario 9. Figure 13 (see Appendix A.1) shows the piezometric surface for Layer 4, the deeper bedrock. The predicted flow in the horizontal well is 1,916.0 m^3/day. The predicted hydraulic head in Test Cell 1 in Layer 2 is 187.76 masl, which is 23 cm above the bedrock surface. Lowering the drain 0.25 m along its length resulted in a head in Test Cell 1 of 187.46 masl, which is 7 cm below the bedrock surface. The predicted hydraulic head in Test Cell 2 is 187.03 masl which is 76 cm below the bedrock surface. The hydraulic head in Test Cell 3 is 188.04 masl which is 38 cm below the bedrock surface.

Figure 14 (see Appendix A.1) shows the predicted saturated thickness of the deeper overburden for this scenario. This figure shows that the overburden is dewatered under the western part of the engineered cover, but that there is a band of saturated overburden along the western bank of the Moira River. These results suggest that, if this scenario is implemented, the eastern boundary of the engineered cover and any leachable wastes in contact with groundwater in the area, should be moved westward.

The predicted flows to the pumping stations under this scenario are summarized in Table 11. As shown in Table 11, there is a significant reduction in flow to all of the pumping stations compared to the base model. The pumping wells for PS4 and PS5 were made inactive in the model (no pumping) after it was determined that the overburden was dewatered in the area of these wells. The table reflects no pumping from these wells.

TABLE 11
PREDICTED PUMPING STATION FLOWS, SCENARIO 9

Zone	Pumping Station	Existing Conditions Flow (m^3/day)	Predicted Base Model Flow (m^3/day)	Base Model Percent of Existing Conditions Flow	Predicted Scenario 9 Flow (m^3/day)	Scenario 9 Percent of Existing Conditions Flow
Zone 3	PS3	112.7	72.5	64.3	46.1	40.9
Zone 7	PS1 and PS2	15.0	3.0	20.0	1.2	8.0
Zone 8	PS4	86.7	38.3	44.2	0	0
Zone 9	PS5	40.7	18.1	44.5	0	0

Reverse particle tracking was carried out for this scenario with particles placed on both sides of the drain and tracked backward to their point of origin. Figure 12 shows the predicted reverse groundwater flow pathlines in the shallow bedrock. The limited number of pathlines in the shallow bedrock shows that the potential for contamination of the horizontal well due to flow of groundwater from the shallow bedrock under the engineered cover is low.

Figure 13 (see Appendix A.1) shows predicted pathlines in the deeper bedrock. These figures show that most of the groundwater flow to the horizontal well is from the deeper bedrock west of the engineered cover, with a component of flow from the north. The overall potential for contamination of the well from flow of groundwater from under the engineered cover is low.

4.10 Scenario 10: Scenario 9 with (Partial) Grout Curtain/ Impermeable Wall

For Scenario 10, the north-south horizontal well with the same configuration as in Scenario 9 (Figure 12) was incorporated into the base model, along with the partial grout curtain/wall adjacent to the north and west sides of the engineered cover, to 2 m below the bedrock surface, with the same configuration as in Scenario 4 (Figure 5).

The predicted flow in the horizontal well is 1,126.5 m^3/day. The predicted hydraulic head in Test Cell 1 in Layer 2 is 186.75 masl which is 0.78 m below the bedrock surface. The saturated thickness of the overburden in Test Cell 1 is therefore, 0.0m. The saturated thickness of the overburden in Test Cells 2 and 3 are also 0.0m.

The modelling indicated that a strip of overburden along the west bank of the Moira River would remain saturated under this remediation scenario. Therefore, if this scenario is implemented, any leachable waste in this area that is in contact with the groundwater, should be excavated and moved westward. The eastern limit of the proposed engineered cover should also be moved westward to correspond with the zero saturated thickness line.

The predicted flows to the pumping stations under this scenario are summarized in Table 12. As shown in Table 12, there is a significant reduction in flow to all of the pumping stations compared to the base model. The results of the modelling indicate that the incorporation of the grout curtain/wall did not significantly affect the flows to pumping stations 1, 2 and 3, compared to Scenario 9. The pumping wells for PS4 and PS5 were made inactive in the model (no pumping) after it was determined that the overburden was dewatered in the area of these wells. The table reflects no pumping from these wells.

TABLE 12
PREDICTED PUMPING STATION FLOWS, SCENARIO 10

Zone	Pumping Station	Existing Conditions Flow (m^3/day)	Predicted Base Model Flow (m^3/day)	Base Model Percent of Existing Conditions Flow	Predicted Scenario 10 Flow (m^3/day)	Scenario 10 Percent of Existing Conditions Flow
Zone 3	PS3	112.7	72.5	64.3	45.1	40.0
Zone 7	PS1 and PS2	15.0	3.0	20.0	0.85	5.7
Zone 8	PS4	86.7	38.3	44.2	0	0
Zone 9	PS5	40.7	18.1	44.5	0	0

Reverse groundwater flow pathline modelling showed similar results to Scenario 9 without the grout curtain. The modelling results indicate that there are no apparent advantages to installing the grout curtain, with the exception of lowered flow in the horizontal well.

4.11 Scenario 11: "Level" Horizontal Well, from North of the Tuttle Shaft, to the East-West Site Access Road, Connected to a HDPE Pipe with Outlet at the Moira River

For Scenario 11, a "level" horizontal well, from north of the Tuttle Shaft, to the east-west site access road, was incorporated into the base model (Figure 15 [see Appendix A.1]). The horizontal well was connected to a high density polyethylene (HDPE) pipe that extends to the Moira River at the southwestern property boundary. The elevation and slope of this pipe was selected to accommodate the head loss in the pipe from the horizontal well to the outlet at the Moira River, which is at an elevation of 184.66 masl where the river meets the property line.

The head loss for the HDPE pipe was calculated by two methods to be 0.6 and 0.62 m over the 373 m of pipe from the end of the horizontal well to the river. The elevation of the level horizontal well would therefore be 185.3 masl along its length. At the point opposite the centre of the equalization pond, the horizontal well is approximately 4 m below the bedrock surface.

Two additional layers were added to the base model in the deep bedrock for Scenarios 11 and 12. The horizontal well was placed in Layer 4 and the vertical relief wells (Scenario 12 - see below) were placed in the bottom layer, Layer 5.

Figure 15 shows the predicted steady state piezometric surface for Layer 3, the top of the bedrock, for Scenario 11. Figure 16 (see Appendix A.1) shows the predicted piezometric surface for Layer 5, the deeper bedrock, for Scenario 11. These figures show that the predicted hydraulic gradient along the horizontal well results in flow into the horizontal well screen and flow from north to south along the horizontal well alignment.

The predicted flow in the horizontal well is 880.5 m^3/day. The modelling results indicate that the predicted hydraulic head in Test Cell 1 in Layer 2, deeper overburden, is 188.5 masl. The bedrock surface elevation in this cell is 187.53 masl. Therefore, the saturated thickness of the overburden is 0.97 m in Test Cell 1. The saturated thicknesses of the overburden in Test Cells 2 and 3 are 0.48 m and 0.68 m, respectively.

Figure 17 (see Appendix A.1) shows the saturated thickness of the deeper overburden. A small part of the area under the equalization pond has a saturated thickness of 0.5 m or greater. As shown in Figure 17, a strip of overburden along the west bank of the Moira River would remain saturated under this remediation scenario. Therefore, if this scenario is implemented, any leachable waste in this area that is in contact with the groundwater, should be excavated and moved westward. The eastern limit of the proposed engineered cover should also be moved westward to correspond with the zero saturated thickness line.

The predicted flows to the pumping stations under this scenario are summarized in Table 13. As shown in Table 13, there is a significant reduction in flow to all of the pumping stations compared to the base model. Modelling results indicate that the predicted flows to PS3 are higher than in Scenario 9. The pumping wells for PS4 and PS5 were made inactive in the model (no pumping) after it was determined that the overburden was dewatered in the area of these wells. The table reflects no pumping from these wells.

TABLE 13
PREDICTED PUMPING STATION FLOWS, SCENARIO 11

Zone	Pumping Station	Existing Conditions Flow (m^3/day)	Predicted Base Model Flow (m^3/day)	Base Model Percent of Existing Conditions Flow	Predicted Scenario 11 Flow (m^3/day)	Scenario 11 Percent of Existing Conditions Flow
Zone 3	PS3	112.7	72.5	64.3	58.0	51.5
Zone 7	PS1 and PS2	15.0	3.0	20.0	1.49	9.9
Zone 8	PS4	86.7	38.3	44.2	0	0
Zone 9	PS5	40.7	18.1	44.5	0	0

Reverse particle tracking was carried out for this scenario with particles placed on both sides of the drain and tracked backward to their point of origin. There are virtually no pathlines in the deeper overburden under the engineered cover, indicating minimal groundwater flow from the deeper overburden to the horizontal well (not shown).

Figure 15 shows reverse groundwater flow pathlines in the shallow bedrock to the horizontal well. This figure shows almost no groundwater movement to the horizontal well from the shallow bedrock under the engineered cover. Figure 16 shows groundwater flow pathlines in the deeper bedrock, where the horizontal well is located. It is apparent from this figure, that most of the groundwater flow is in the deeper bedrock and originates from the west of the Industrial Area, with a component of flow from the north.

The potential for contamination from the shallow bedrock under the shallow engineered cover entering the horizontal well is low and, as most of the groundwater flow would likely be uncontaminated groundwater from the west and north, the dilution will be high.

The water levels in the municipal Deloro Well and the Tuttle Shaft were compared for existing conditions and Scenario 11. The modelled water levels are shown in Table 14.

TABLE 14
COMPARISON OF MODELLED WATER LEVELS IN DELORO WELL AND TUTTLE SHAFT

Well	Static Water Level Elevation (masl)	Existing Conditions Pumping Water Elevation (masl)	Scenario 11 Pumping Water Level Elevation (masl)
Deloro Well	197.36	194.60	192.94
Tuttle Shaft	194.03	189.89	189.11

The difference in drawdown between the existing conditions pumping level and the Scenario 11 pumping level is 1.66 m in the Deloro Well. This indicates there will still be adequate available drawdown to maintain the village's water needs. The available drawdown under existing conditions is 19.8 m. The available drawdown under this scenario is 18.1 m.

In the Tuttle Shaft, the predicted reduction in groundwater level from existing conditions to Scenario 11 is 0.78 m. This may be significant enough to reduce artesian flow from the Tuttle Shaft; however, more information is needed to determine the impact of this scenario on the Tuttle Shaft flow.

The relative drawdown differences are dependant on the pumping rate. However, given the same pumping rate for existing conditions and Scenario 11 for the Deloro Well and the Tuttle Shaft, the model results should be representative.

4.12 Scenario 12: Scenario 11 with Eight Vertical Pressure Relief Wells in the Deeper Bedrock

For Scenario 12, the horizontal well used for Scenario 11 was included in the base model. The model also incorporated eight pressure relief wells, placed into the deeper bedrock (Figure 18 [see Appendix A.1]) and adjacent to the engineered cover. The vertical bedrock wells were incorporated into this scenario to allow groundwater to flow from the deeper bedrock by artesian pressure to the horizontal well. The eight wells in the deeper bedrock were represented as constant heads at the same elevation of the horizontal well, 185.3 masl.

An indication of the area's available artesian pressure was obtained from the static water level in the municipal Deloro Well, in relation to where the groundwater was encountered. The static groundwater level in this well was reported to be 10.1 m below the top of the well in the well log. The well log indicates that groundwater was encountered at a depth of approximately 30 m. This indicates significant artesian pressure in the area, supporting the hypothesis that deep vertical bedrock wells can be used with a horizontal well to depressurize the deeper bedrock, thereby reducing upward groundwater flow from the bedrock into the overburden beneath the waste area.

Figure 18 shows the predicted steady state piezometric surface for Layer 3, the top of the bedrock, for Scenario 12. Figure 19 (see Appendix A.1) shows the predicted piezometric surface for Layer 5, the deeper bedrock. These figures show that the predicted hydraulic gradient along the horizontal well results in flow into the horizontal well screen and flow from north to south along the horizontal well alignment.

The horizontal drain conveyed 645.3 m^3/day, and the connected vertical wells conveyed 314.2 m^3/day, for a total flow of 959.5 m^3/day. It should be stressed that these are very preliminary numbers and should not be used as the basis for design.

The predicted hydraulic head in Test Cell 1, Layer 2 is 187.60 masl. The bedrock surface elevation in this cell is 187.53 m indicating 7 cm of saturated thickness in the deeper overburden. The hydraulic head in Test Cell 2 is 0.33 m below the bedrock surface. The hydraulic head in Test Cell 3 is 0.15 m below the bedrock surface.

Figure 20 (see Appendix A.1) shows the predicted saturated thickness of the deeper overburden, Layer 2. The figure shows that the deeper overburden under the engineered cover is dewatered, but that a strip of saturated overburden along the west bank of the Moira River remains. If this scenario is implemented, these results suggest that the eastern limit of the engineered cover, and any leachable waste in contact with the groundwater, should be moved westward to the dewatered area.

The modelling results indicate that Scenario 12 has the potential to reduce the flow of groundwater from the overburden and bedrock into the waste area. However, at this time, further modelling to lower the piezometric surface in Test Cell 1 is not warranted. It is apparent that some number of deep vertical relief wells could work. However, further field work is needed to evaluate the hydraulic characteristics of the deep and shallow bedrock along the proposed alignment of the horizontal well.

The individual flow from each of the eight vertical relief wells (assuming equal flow) is 39.3 m^3/day. These yields seem to be achievable when compared to the yield of the Deloro Well. The average pumping rate from the Deloro Well is 76.3 m^3/day, and the Permit to Take Water rate is 327.0 m^3/day, which is indicative of the well's maximum sustainable yield. The well taps a confined aquifer (fracture zone) at approximately 30 m deep, with the static water level at a depth of 10 m.

The predicted flows to the pumping stations under this scenario are summarized in Table 15. As shown in Table 15, there is a significant reduction in flow to all of the pumping stations compared to the base model. Modelling results indicate that the predicted flows to PS3 are higher than in Scenario 9 and lower than in Scenario 11. The pumping wells for PS4 and PS5 were made inactive in the model (no pumping) after it was determined that the overburden was dewatered in the area of these wells. The table reflects no pumping from these wells.

TABLE 15
PREDICTED PUMPING STATION FLOWS, SCENARIO 12

Zone	Pumping Station	Existing Conditions Flow (m^3/day)	Predicted Base Model Flow (m^3/day)	Base Model Percent of Existing Conditions Flow	Predicted Scenario 12 Flow (m^3/day)	Scenario 12 Percent of Existing Conditions Flow
Zone 3	PS3	112.7	72.5	64.3	54.7	48.6
Zone 7	PS1 and PS2	15.0	3.0	20.0	1.18	7.9
Zone 8	PS4	86.7	38.3	44.2	0	0
Zone 9	PS5	40.7	18.1	44.5	0	0

Reverse particle tracking was carried out for this scenario with particles placed on both sides of the drain (and the vertical wells) and tracked backward to their point of origin. Figure 18 shows the predicted reverse groundwater flow pathlines in the shallow bedrock, Layer 3. There are very few pathlines in the shallow bedrock, which indicates almost no groundwater movement to the horizontal well from the shallow bedrock under the engineered cover. Figure 19 shows groundwater flow pathlines in the deeper bedrock, where the horizontal well is located. It is apparent from this figure that most of the groundwater flow is in the deeper bedrock and originates from the west of the Industrial Area, with a component of flow from the north.

With this scenario, there will be some groundwater flow from shallow bedrock under the engineered cover to the deeper bedrock, and then to the horizontal well. Thus, there is some potential for contaminated water to get into the horizontal well. Given that most of the water entering the horizontal well is likely uncontaminated groundwater from the west and north of the site, the dilution factor will likely be high. Further evaluation of this dilution factor is provided below.

The modelled pumping levels in the municipal Deloro Well and the Tuttle Shaft for Scenario 12 are compared to existing conditions and Scenario 11 in Table 16. The pumping water levels are slightly lower for Scenario 12.

TABLE 16
COMPARISON OF MODELLED WATER LEVELS IN DELORO WELL AND TUTTLE SHAFT

Well	Static Water Level Elevation (masl)	Existing Conditions Pumping Water Elevation (masl)	Scenario 11 Pumping Water Level Elevation (masl)	Scenario 12 Pumping Water Level Elevation (masl)
Deloro Well	197.36	194.60	192.94	192.65
Tuttle Shaft	194.03	189.89	189.11	189.00

Figure 21 (see Appendix A.1) shows the difference in piezometric surface of the deeper overburden for existing conditions with the piezometric surface of the same layer for Scenario 12. The predicted changes in groundwater levels increase westerly from a 0.5 m reduction at the Moira River to an 8.5 m reduction at the horizontal well.

Table 17 shows a comparison of calculated water level elevations for existing conditions and Scenario 12 for selected monitoring wells. As shown in Table 17, the predicted reduction in groundwater elevations for these overburden wells ranged from 0.78 m to 6.58 m, and for the bedrock wells from 0.62 m to 5.73 m.

TABLE 17
COMPARISON OF PREDICTED GROUNDWATER ELEVATIONS FOR SCENARIO 12 TO EXISTING CONDITIONS

Groundwater Monitor	Existing Conditions Groundwater Elevation (masl)	Scenario 12 Predicted Groundwater Elevation (masl)	Scenario 12 Predicted Reduction in Groundwater Elevation (masl)
Overburden			
GA-14	188.63	187.85	0.78
GA-8	196.8	192.21	4.59
GA-7	195.29	188.71	6.58
GA-6	193.1	187.76	5.34
GA-3	191.63	187.79	3.84
GA-5	191.56	187.36	4.20
Bedrock			
GA-9	193.77	188.04	5.73
GR4-2	191.05	189.28	1.77
GR3-2	188.92	188.30	0.62
GA12-1	193.57	189.93	3.64
GA2-1	192.45	188.35	4.10
GR3-1	189.3	188.28	1.02
GR-12	191.44	187.29	4.15

The MODFLOW program, Zone Budget, was used to distinguish presumably uncontaminated groundwater flows originating from the west of the site, from groundwater flows originating under the engineered cover which may be affected by leachate from the wastes. Table 18 summarizes the flows estimated from this analysis.

TABLE 18
SUMMARY OF PREDICTED FLOWS USING ZONE BUDGET

Zone	Predicted Flow to Horizontal and Vertical Wells for Scenario 12 (m^3/day)	Predicted Flow from Shallow Bedrock to Deeper Bedrock (m^3/day)
Flow From West in Deeper Bedrock	641.2	
Flow From Under the Engineered Cover in Deeper Bedrock	309.2	
Flow from Shallow Bedrock to Deeper Bedrock From Under the Engineered Cover		73.8
Flow from Shallow Bedrock to Deeper Bedrock to West of Horizontal Well		325.1

In Table 18, the flow from the shallow bedrock to the deeper bedrock under the engineered cover, 73.8 m^3/day, becomes part of the 309.2 m^3/day flowing from under the engineered cover in the deeper bedrock to the horizontal and vertical wells. Similarly, the flow from the shallow bedrock to the deeper bedrock west of the horizontal well, 325.1 m^3/day, becomes part of the 641.2 m^3/day flowing from the deeper bedrock to the horizontal and vertical wells.

The flow from the west in the deeper bedrock is more than twice the flow from under the engineered cover in the deeper bedrock. However, flow from the shallow bedrock to the deeper bedrock is 73.8 m^3/day or 22.7 percent of the flow from the shallow bedrock to the deeper bedrock on the west side of the horizontal well. The dilution for groundwater coming from the shallow bedrock under the engineered cover to the horizontal well and vertical wells (i.e. 73.8 m^3/day) compared to the entire flow in the system (i.e. 950.4 m^3/day) is a factor of 12.9:1.

4.13 Summary of Modelling Results for All Remediation Scenarios

Table 19 provides a summary of the modelling results for each scenario.

TABLE 19
SUMMARY OF REMEDIATION SCENARIO MODELLING RESULTS

Scenario	Description	Flow (m^3/day)	Saturated Thickness Layer 2 (m)			Comments
			Cell 1	Cell 2	Cell 3	
	Base Model		5.09			
1	Base Model with Shallow Perimeter Drain	Drain 60.9	4.81			Insignificant water level lowering in the overburden
2	Grout Curtain 2 m into Bedrock Around Most of the North, West, and South Sides of the Engineered Cover		4.5			Minor water level lowering in the overburden, grout curtain on the south side is counterproductive
3	Grout Curtain 2 m into Bedrock on North and West Sides of Engineered Cover – Partial Wall		4.38			Minor water level lowering in the overburden
4	Grout Curtain as in Scenario 3 with Shallow Perimeter Drain as in Scenario 1	Drain 81.5	4.23			Minor water level lowering in the overburden
5	Partial Wall to 6 m Depth with Shallow Interceptor Drain	Drain 86.2	4.34			Slightly higher water level in Test Cell 1 than in Scenario 4
6	Deep Interceptor Wells on North and West Sides of Engineered Cover	Well Flow 700	0.0	0.08	0.16	Deeper overburden almost dewatered with this scenario, increasing well yield likely could achieve dewatering
7	Partial Wall to 2 m into the Bedrock with Deep Interceptor Wells	Well Flow 675	0.0	0.0	0.0	Complete dewatering of overburden
8	Horizontal Well 0.5% Slope, on North and West Sides of Engineered Cover, Outlet 175 m South of East-West Access Road at Natural Marsh	Horizontal Well 1,557.6	0.0	0.0	0.0	Necessary to pump water conveyed by horizontal well since outlet is 6 m below river level
9	Horizontal Well from North of Tuttle Shaft, South to Natural Marsh Lake as in Scenario 8	Horizontal Well 1,916.0	0.0	0.0	0.0	Necessary to pump water conveyed by horizontal well since the outlet is 6 m below river level
10	Scenario 9 with Partial Wall to 2 m Below Bedrock Surface	Horizontal Well 1,126.5	0.0	0.0	0.0	Less flow in horizontal well may reflect decreased flow from bedrock under the engineered cover, necessary to pump water from horizontal well to river

TABLE 19
SUMMARY OF REMEDIATION SCENARIO MODELLING RESULTS

Scenario	Description	Flow (m^3/day)	Saturated Thickness Layer 2 (m)			Comments
			Cell 1	Cell 2	Cell 3	
11	Level Horizontal Well from North of Tuttle Shaft to East-West Road on West Side of Engineered Cover, HDPE Pipe Conveys Water to River	Horizontal Well 880.5	0.97	0.48	0.68	Designed to enable gravity flow to river. Approximately 1 m saturated overburden under the equalization pond area. Reduction in pumping water level in Tuttle Shaft of 0.78 m, may reduce artesian flow, drawdown in Deloro Well is 1.66 m, not significant. Relatively little groundwater flow from overburden or shallow bedrock under engineered cover to horizontal well in deeper bedrock.
12	Scenario 11 with Eight Vertical Relief Wells in the Deeper Bedrock Which Allow Water to Flow to the Horizontal Well by Artesian Flow	Horizontal Well 645.3 Vertical Relief Wells (8) 314.2	0.07	0.0	0.0	Almost complete dewatering of overburden. Number of wells needs to be determined from field work. Discharge flows by gravity to Moira River. Pumping water levels in Deloro Well and Tuttle Shaft reduced slightly from previous scenario.

5. Conclusions

Based on the modelling results for the 12 remediation scenarios described in previous sections of the report, the following conclusions are presented:

1. The shallow perimeter drain has little effect on dewatering the overburden.
2. The full or partial grout curtains, by themselves, will not be effective in dewatering the overburden.
3. The full or partial grout curtains combined with the shallow perimeter drain are not effective in dewatering the overburden.
4. The deeper grout curtain to 6 m below the bedrock surface combined with the shallow interceptor drain is not effective in dewatering the overburden.
5. Interceptor wells on the north and west sides of the proposed engineered cover appear to be able to effect dewatering of the overburden under the engineered cover. The pumping rates of the wells for this scenario could be more than 700 m^3/day. Particle tracking indicates that most of the groundwater pumped by the wells originates from the north and west of the site, indicating that the water will likely be relatively uncontaminated.
6. Combining a partial grout curtain to 2 m below the bedrock surface with the interceptor wells will achieve dewatering of the overburden with marginally less water pumped from the wells. In both Scenario 6 and 7, the line of zero saturated thickness adjacent to the west bank of the Moira River is under the eastern edge of the proposed engineered cover. This indicates that the eastern extent of the cover and any leachable waste in contact with the groundwater may have to be moved westward. This is true for the remaining scenarios.
7. A horizontal well of 0.5 percent slope placed in the bedrock just outside the north and west sides of the proposed engineered cover will achieve dewatering of the overburden if the elevation of the well is less than 184.21 masl immediately west of Test Cell 1. Since the horizontal well outlet will be at an elevation of 182.8 masl at its outlet in the natural marsh, 175 m south of the east-west access road, water will have to be pumped to the river. If the horizontal well is level, the well would have to be at an elevation of 184.0 masl to achieve dewatering of the overburden. Pumping would still be needed at the outlet.
8. A north-south trending horizontal well in the bedrock which extends north to the area of the Tuttle Shaft will work just as well as Scenario 8. The elevation of the well at its north end is 186.1 masl and 182.3 masl at the southern extension. Adding a partial grout curtain achieves essentially the same dewatering result, but the flow in the horizontal well is 59 percent of the flow without the grout curtain. Whether the drain is horizontal or sloped, pumping would be needed at the outlet to convey water to the river.

9. A north-south horizontal well in the bedrock, capable of discharging by gravity flow to the Moira River, could achieve almost complete dewatering of the overburden. However, there is an area under the equalization pond that still has some saturated thickness, of up to 1 m in the overburden. There is also a strip of saturated overburden along the west side of the Moira River indicating that the eastern edge of the engineered cover and any leachable waste in contact with the groundwater may have to be moved west.

10. A north-south horizontal well in the bedrock, capable of discharging by gravity flow to the Moira River, combined with vertical pressure relief wells appears to be able to almost completely dewater the overburden. The overburden under the equalization pond, which was not completely dewatered in Scenario 11, is dewatered with the addition of the deep vertical relief wells. As in the previous scenario, a strip of saturated overburden on the west bank of the Moira River remains.

11. The modelling indicates that both Scenarios 11 and 12 have sound potential as preferred scenarios. Both are passive solutions requiring no pumping which could potentially dewater most, or all, of the overburden, if desired. In order to determine the feasibility of these options, and the number of vertical wells required, hydrogeologic field investigations and further modelling will be needed to determine the hydraulic characteristics of the deep and shallow bedrock in the area of the horizontal well vertical relief wells. For more details, see the section on Recommendations.

12. The modelled groundwater levels in the municipal Deloro Well predict there will be relatively low interference associated with the groundwater interception of Scenarios 11 and 12. The difference in drawdown between the existing conditions pumping level and the Scenarios 11 and 12 pumping level is up to 1.95 m in the Deloro Well. The available drawdown under existing conditions is 19.8 m. The available drawdown under these scenarios is between 17.9 m and 18.1 m for Scenarios 12 and 11, respectively. This indicates that there will still be adequate available drawdown to maintain the Village's water needs.

13. The pumping water elevation at the Tuttle Shaft is predicted to decline by up to approximately 0.9 m as a result of the groundwater interception of Scenario 12. This may be significant enough to reduce artesian flow from the Tuttle Shaft; however, more information is needed to determine the impact of this scenario on the Tuttle Shaft flow.

6. Recommendations

Modelling has been carried out to determine if a totally passive solution can be used for dewatering of the surficial deposits under the proposed engineered cover. The following recommendations are provided with a view to achieving this preferred objective.

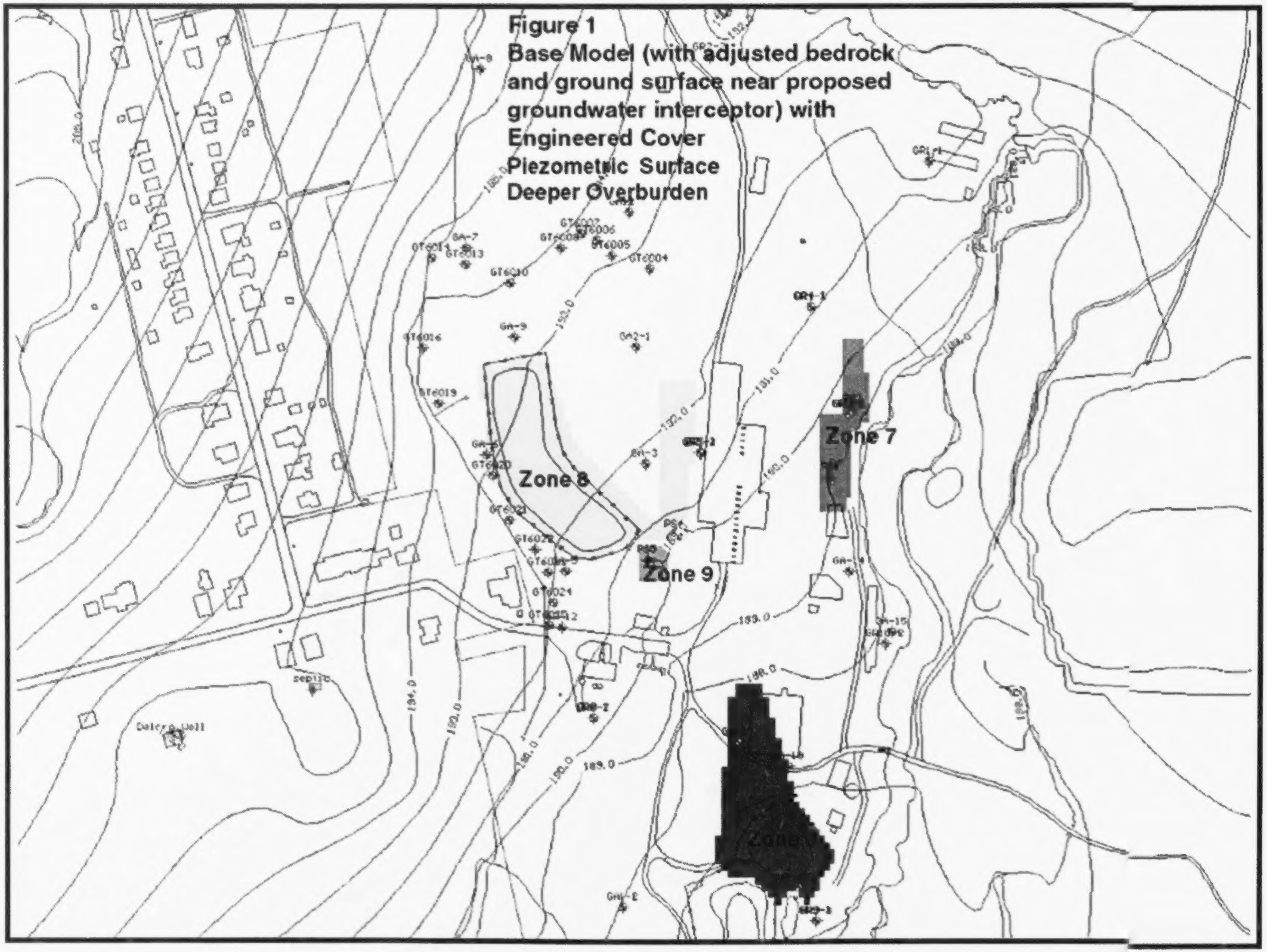
1. The only solutions with passive elements that will almost completely dewater the surficial deposits under the engineered cover include a horizontal drilled well (Scenario 11) and a horizontal drilled well connected to vertical relief wells (Scenario 12) along the west side of the proposed engineered cover. Due to the uncertainty in hydraulic properties along the proposed alignment of the horizontal well, a hydrogeologic field investigation involving drilling and installation of pumping and observation wells, and pumping tests, needs to be carried out.
2. If possible, the field studies should include measurements of the Tuttle Shaft's static water level, in relation to the ground surface, to determine if the horizontal well can depressurize the area so there is no artesian flow.
3. Following completion of the field program and data analysis, further groundwater flow modelling will be required to confirm the original and updated modelling and to determine the effectiveness of the proposed groundwater diversion/control solution. Depending on the data obtained during the field program, this modelling should also include evaluation of an additional groundwater diversion/control scenario. This scenario should incorporate a horizontal well constructed entirely in the overburden, in conjunction with vertical pressure relief wells constructed in the bedrock, to determine if effective groundwater flow control can be achieved.
4. Conservative contaminant transport modelling should be carried out to determine the likelihood of contaminated groundwater entering the horizontal and vertical wells from under the engineered cover. (Currently, it is predicted that groundwater coming from the shallow bedrock under the engineered cover to the horizontal well and vertical wells will be diluted by a factor of approximately 12.9:1, when the entire flow into the system is considered).

Note: Scenario 12 has been adopted in the Draft Industrial Area Closure Plan, since it is a passive solution and is predicted to almost fully dewater the surficial deposits. Additional conceptual details of the horizontal well and vertical pressure relief wells are presented in the Draft Closure Plan, including a cost opinion of the capital and maintenance costs for this system.

APPENDIX A.1

FIGURES

Figure 1
Base Model (with adjusted bedrock and ground surface near proposed groundwater interceptor) with Engineered Cover
Piezometric Surface
Deeper Overburden


Zone 7
Zone 8
Zone 9
Zone
GA-8
GA-7
GA-9
GA2-1
GA-3
GA-14
GA-15
GR1-1
GT6002
GT6003
GT6004
GT6005
GT6006
GT6010
GT6013
GT6014
GT6016
GT6019
GT6020
GT6021
GT6022
GT6024
septic
Delcro Well
192.0
191.0
190.0
189.0
188.0
193.0
194.0
208.0

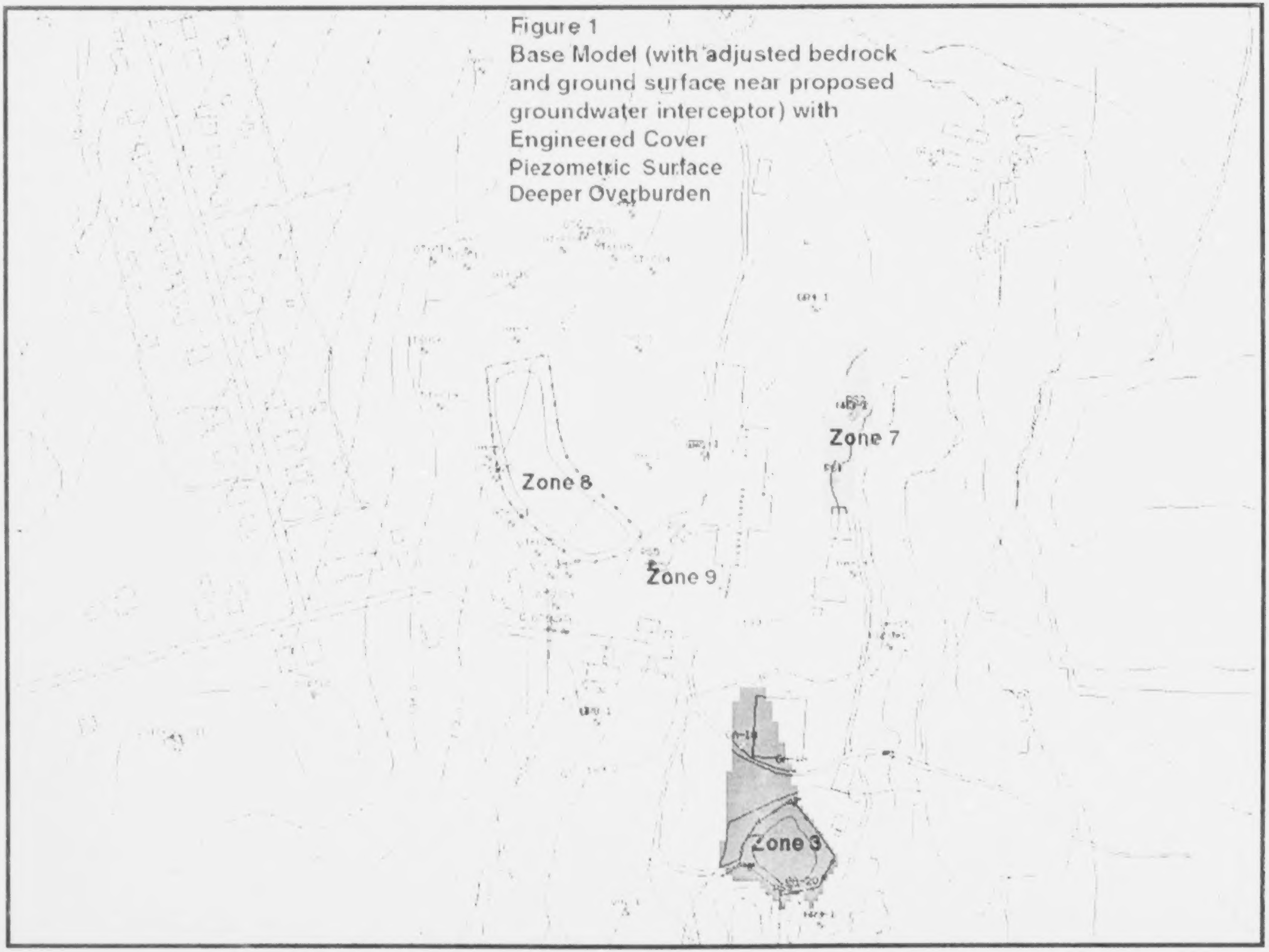


Figure 1
Base Model (with adjusted bedrock and ground surface near proposed groundwater interceptor) with Engineered Cover
Piezometric Surface
Deeper Overburden

Zone 7
Zone 8
Zone 9
Zone 3

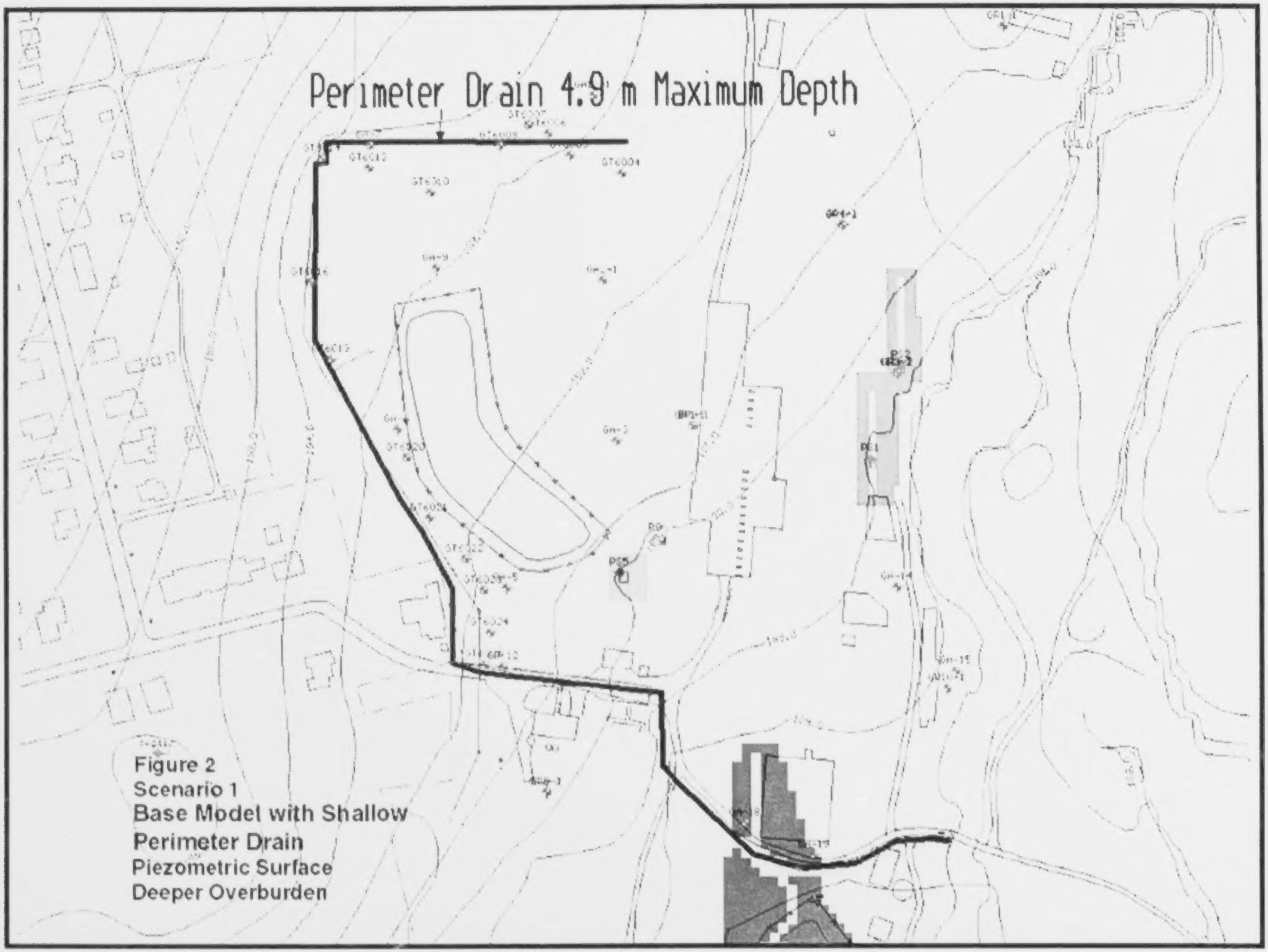

Perimeter Drain 4.9 m Maximum Depth
GTe007
GTe008
GTe013
GTe010
GTe004
GH-9
GH-3
GTe020
GTe022
GTe024
RE1
PS5
GH-14
GH-15

Figure 2
Scenario 1
Base Model with Shallow
Perimeter Drain
Piezometric Surface
Deeper Overburden

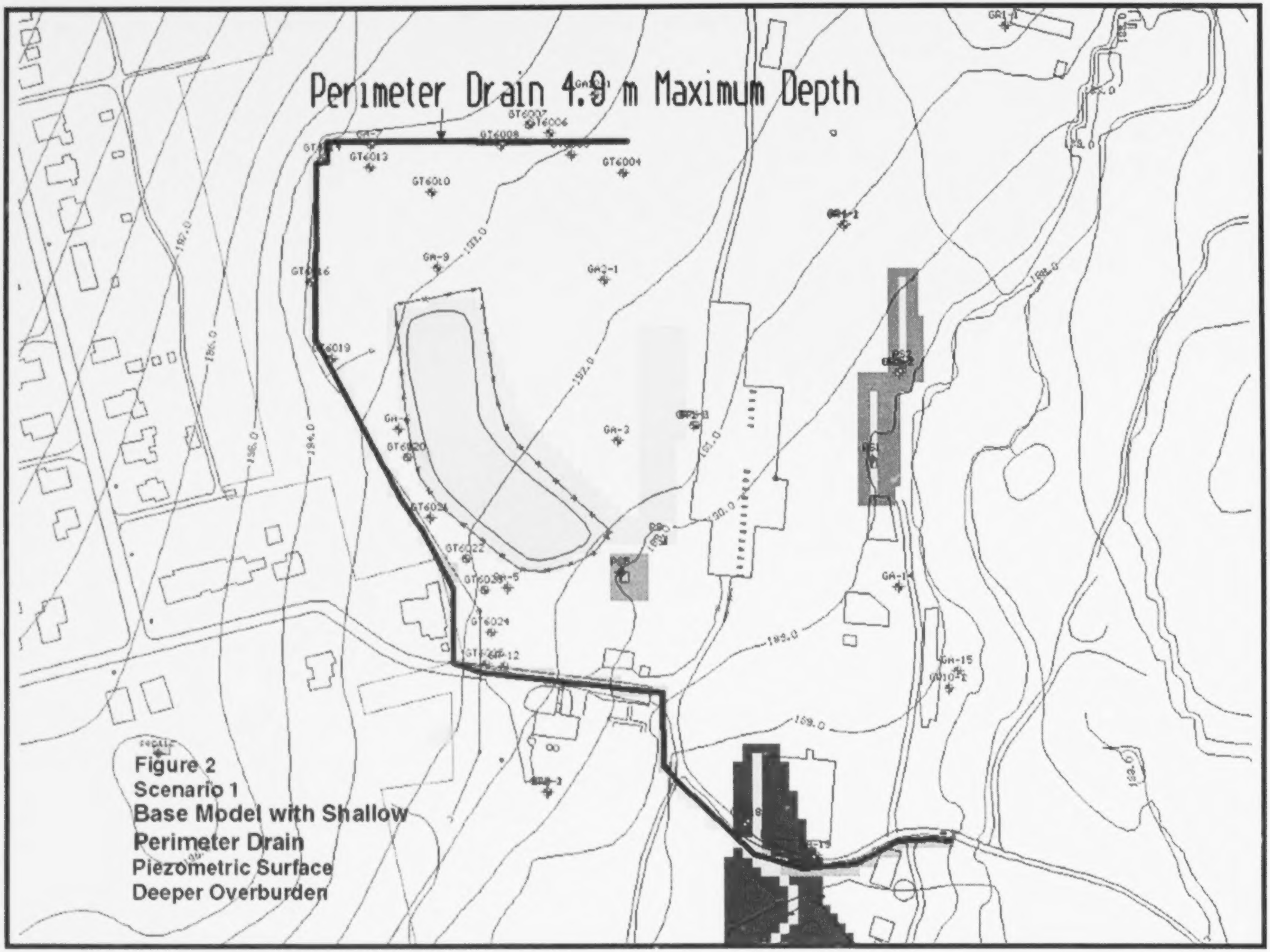

Perimeter Drain 4.9 m Maximum Depth

Figure 2
Scenario 1
Base Model with Shallow
Perimeter Drain
Piezometric Surface
Deeper Overburden

GA-7
GT6013
GT6010
GT6008
GT6007
GT6006
GT6004
GA-9
GA2-1
GA-3
GA-4
GT6020
GT6019
GT6021
GT6022
GT6038
GA-5
GT6024
GA-12
GA-14
GA-15
GU10-1
GA1-1
GA4-1
RS1
RS2
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188.0
184.0
186.0
182.0

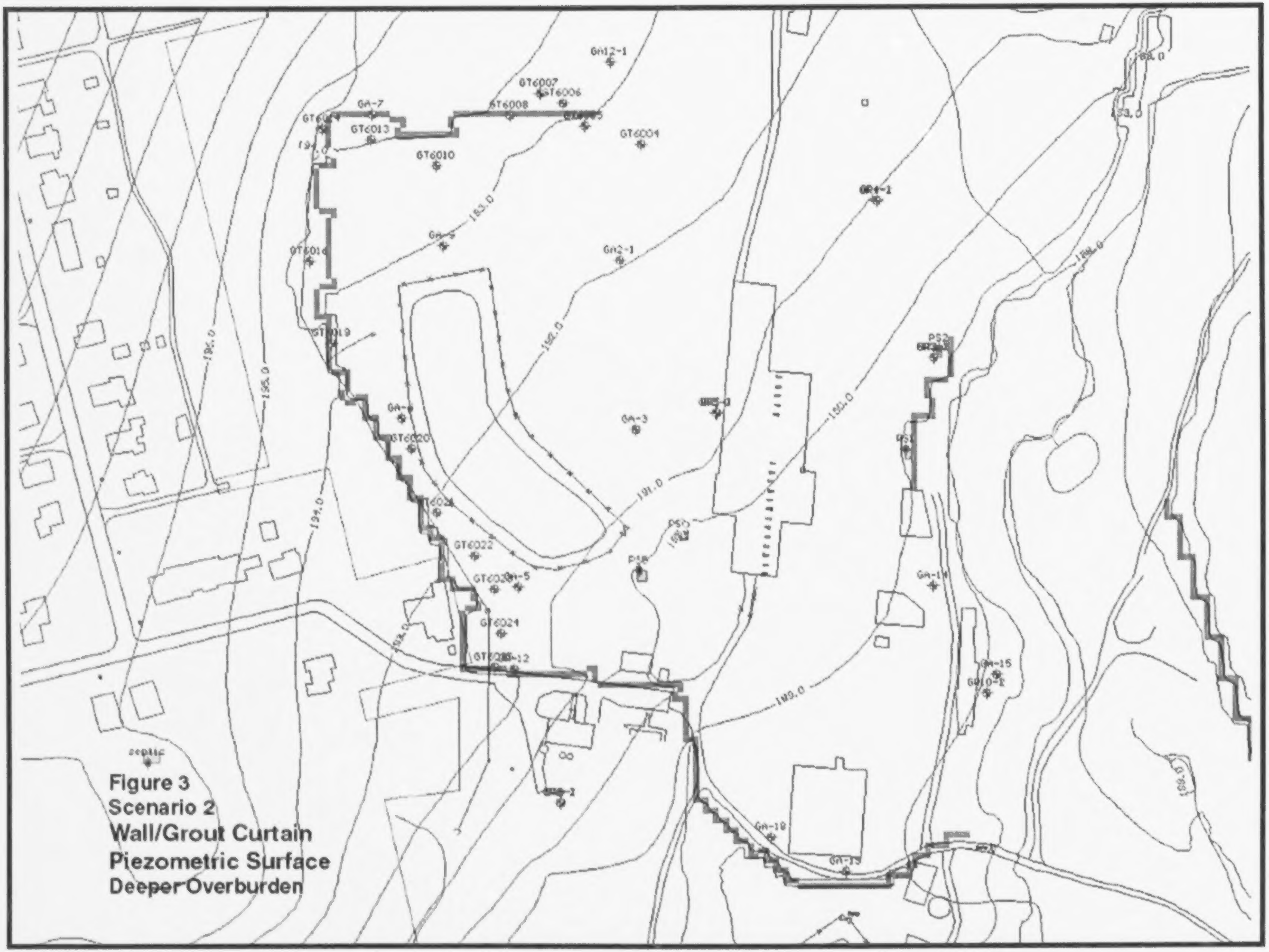
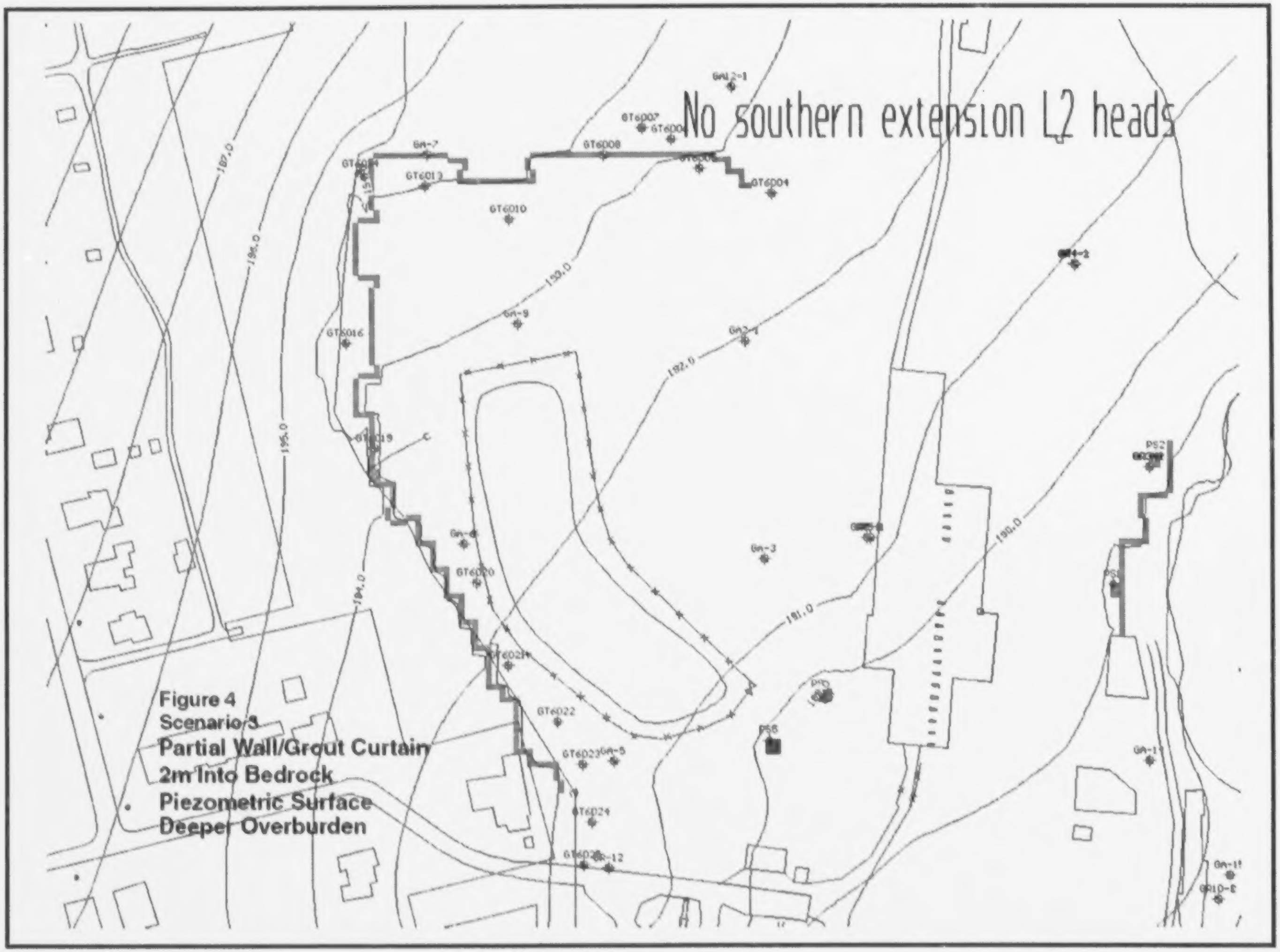
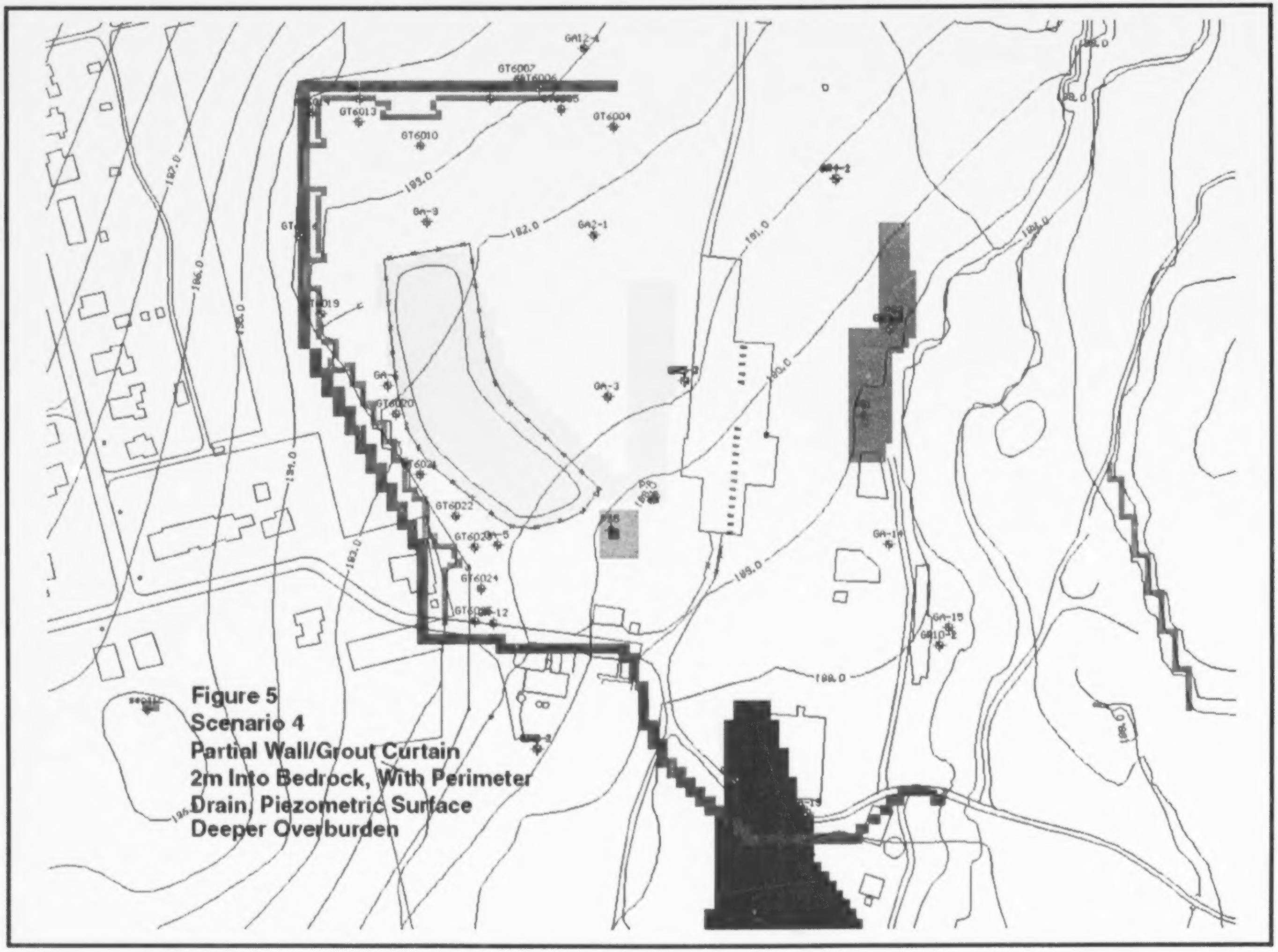

GA12-1
GT6007
GT6006
GT6008
GA-7
GT6013
GT6010
GT6004
GA2-1
GT6016
GT6019
GA-3
GT6020
GT6022
GT6024
GA-14
GA-15
GA-18
GA-13
PS2
PS1
P1B
septic
193.0
192.0
191.0
190.0
189.0
188.0
194.0
195.0
196.0

Figure 3
Scenario 2
Wall/Grout Curtain
Piezometric Surface
Deeper Overburden



No southern extension L2 heads
GA12-1
GT6007
GT6008
GA-7
GT6013
GT6010
GT6004
GA-4-2
GT6016
GA-9
GA2-1
192.0
193.0
187.0
195.0
196.0
194.0
GT6019
C
GA-8
GT6020
GT6021
GT6022
GT6023
GA-5
GT6024
GA-12
GA-3
191.0
190.0
PS2
PS1
PS8
GA-1
GA-11
GR10-3

Figure 4
Scenario 3
Partial Wall/Grout Curtain
2m Into Bedrock
Piezometric Surface
Deeper Overburden


GA12-4
GT6007
GT6006
GT6013
GT6010
GT6004
193.0
GA-3
182.0
GA2-1
GT6019
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GT6020
GT6022
GT6024
192.0
186.0
195.0
194.0
193.0
191.0
190.0
189.0
188.0
186.0
GA-14
GA-15
GA10-2
196.0

Figure 5
Scenario 4
Partial Wall/Grout Curtain
2m Into Bedrock, With Perimeter
Drain, Piezometric Surface
Deeper Overburden

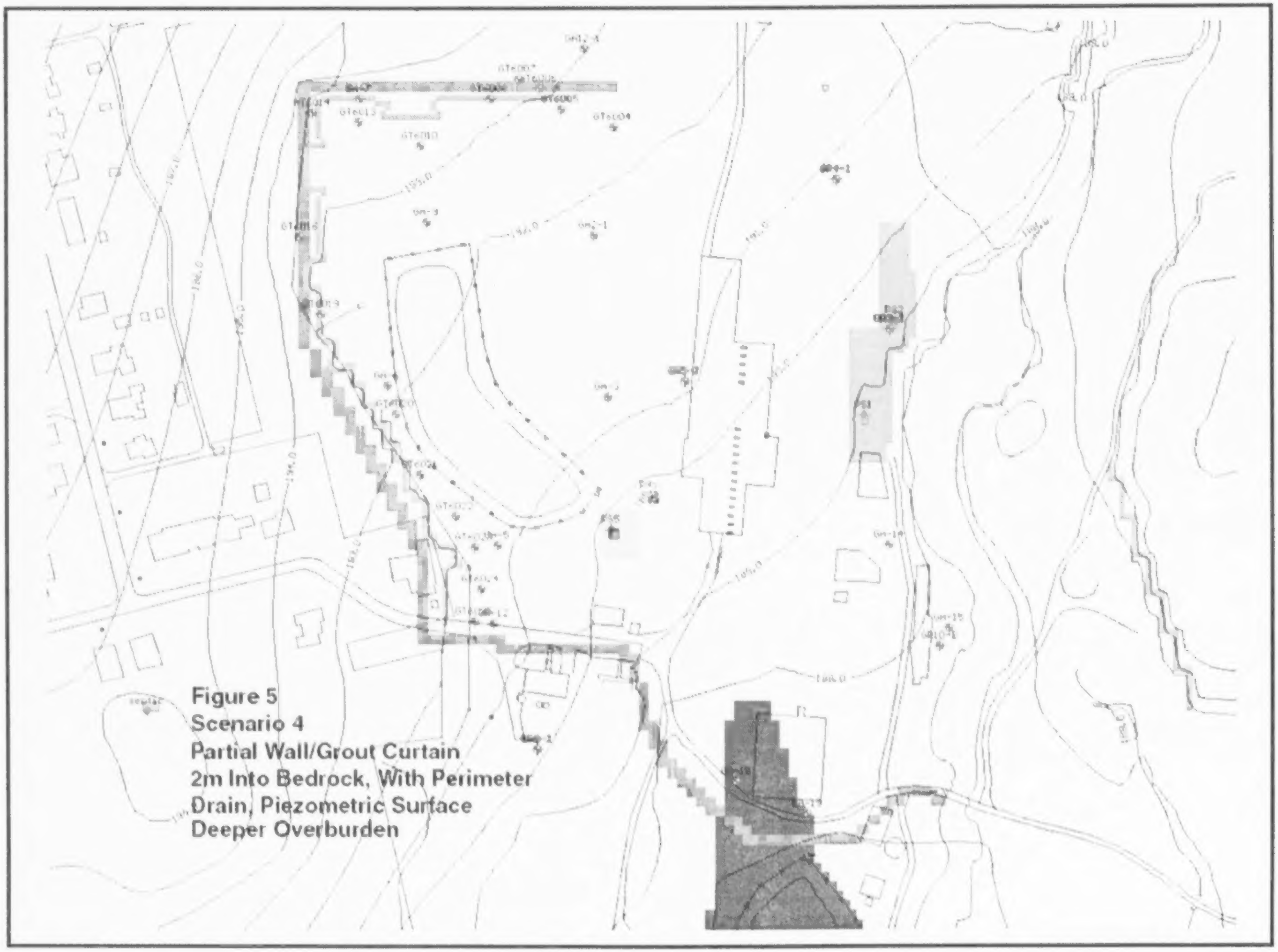


Figure 5
Scenario 4
Partial Wall/Grout Curtain
2m Into Bedrock, With Perimeter
Drain, Piezometric Surface
Deeper Overburden

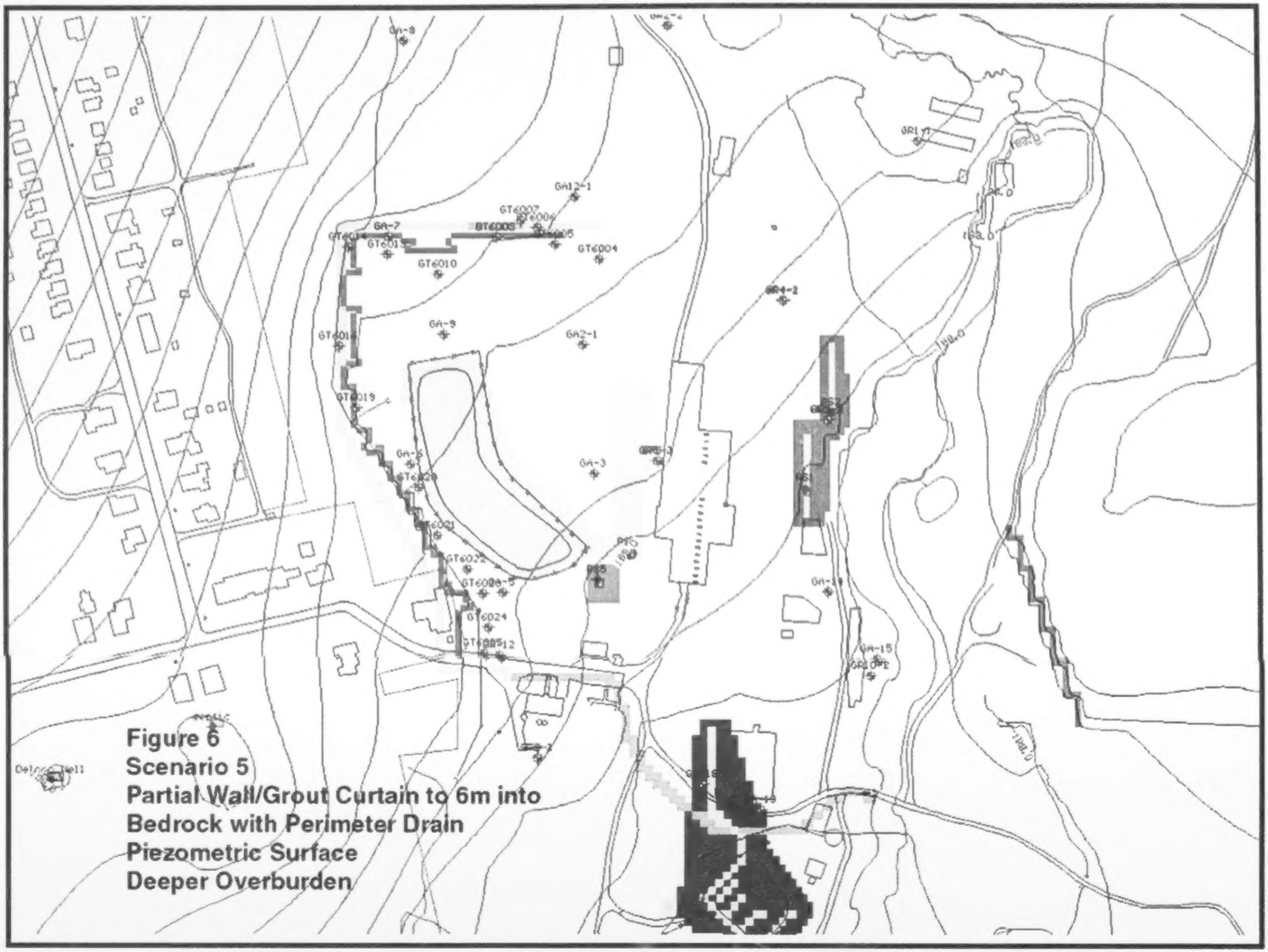

GA-8
GA12-1
GT6007
GT6006
GT6005
GT6004
GA-7
GT6013
GT6010
GT6018
GA-9
GA2-1
GT6019
GA-5
GT6020
GA-3
GT6021
GT6022
GT6024
GA-15
GR4-2
188.0

Figure 6
Scenario 5
Partial Wall/Grout Curtain to 6m into
Bedrock with Perimeter Drain
Piezometric Surface
Deeper Overburden

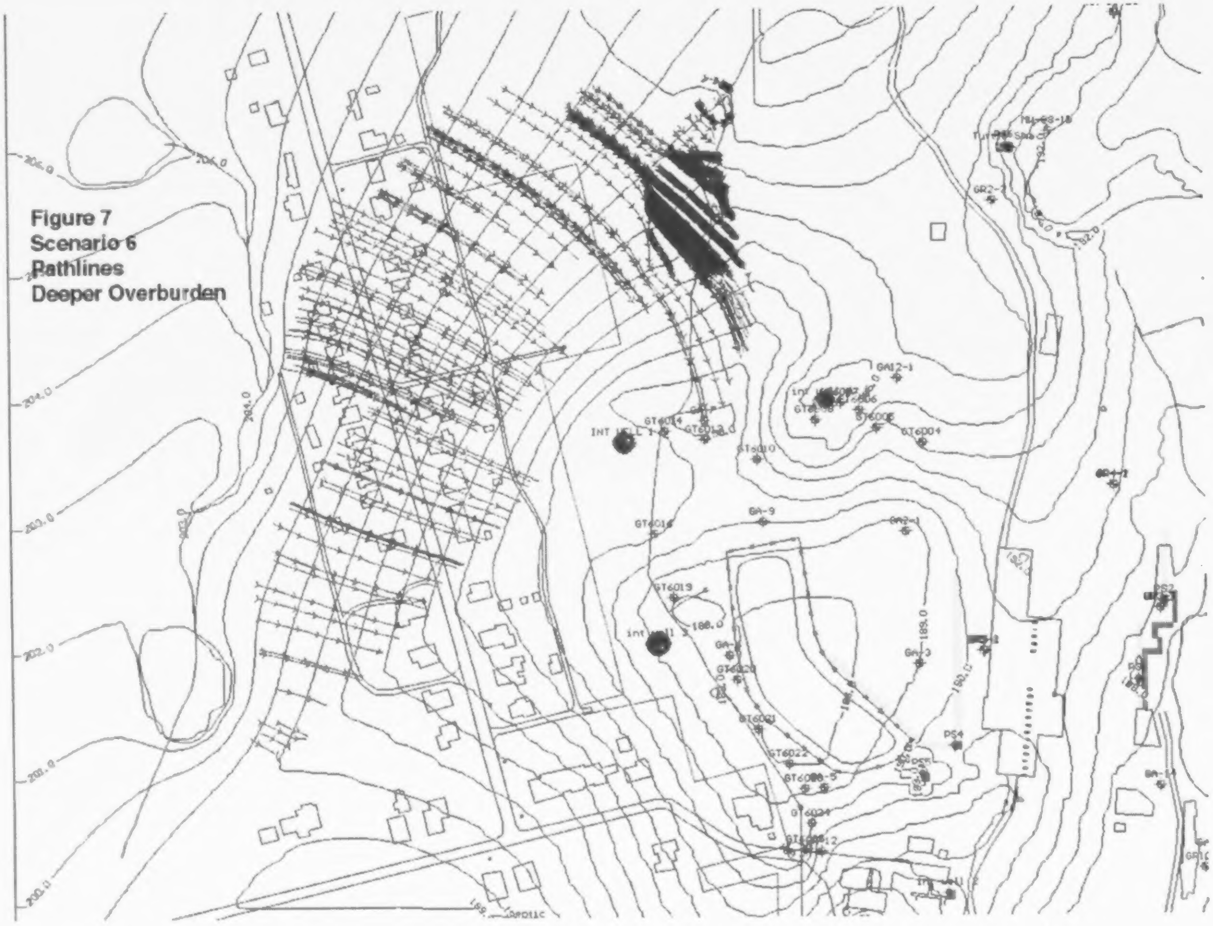
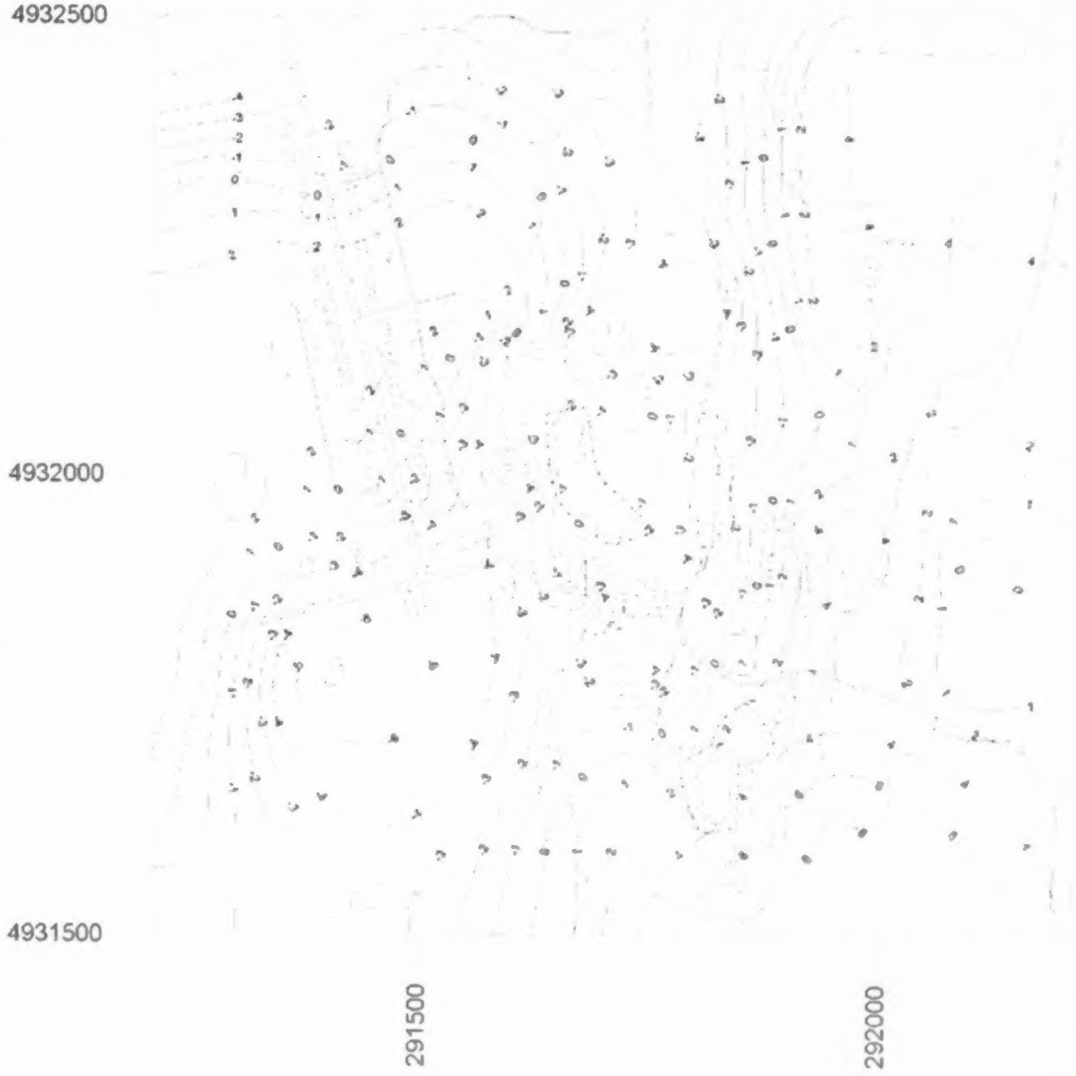

204.0
204.0
204.0
203.0
202.0
201.0
200.0
GR2-2
192.0
GA12-1
GT6006
GT6005
GT6004
INT WELL 1
GT6014
GT6010
GA-9
GT6016
GA2-1
GT6019
188.0
189.0
GA-3
GT6020
190.0
GT6021
PS4
GT6022
GT6024
PS2
GA-1

Figure 7
Scenario 6
Pathlines
Deeper Overburden

Figure 8
Scenario 6
Interceptor Wells No Wall
Saturated Thickness
Deeper Overburden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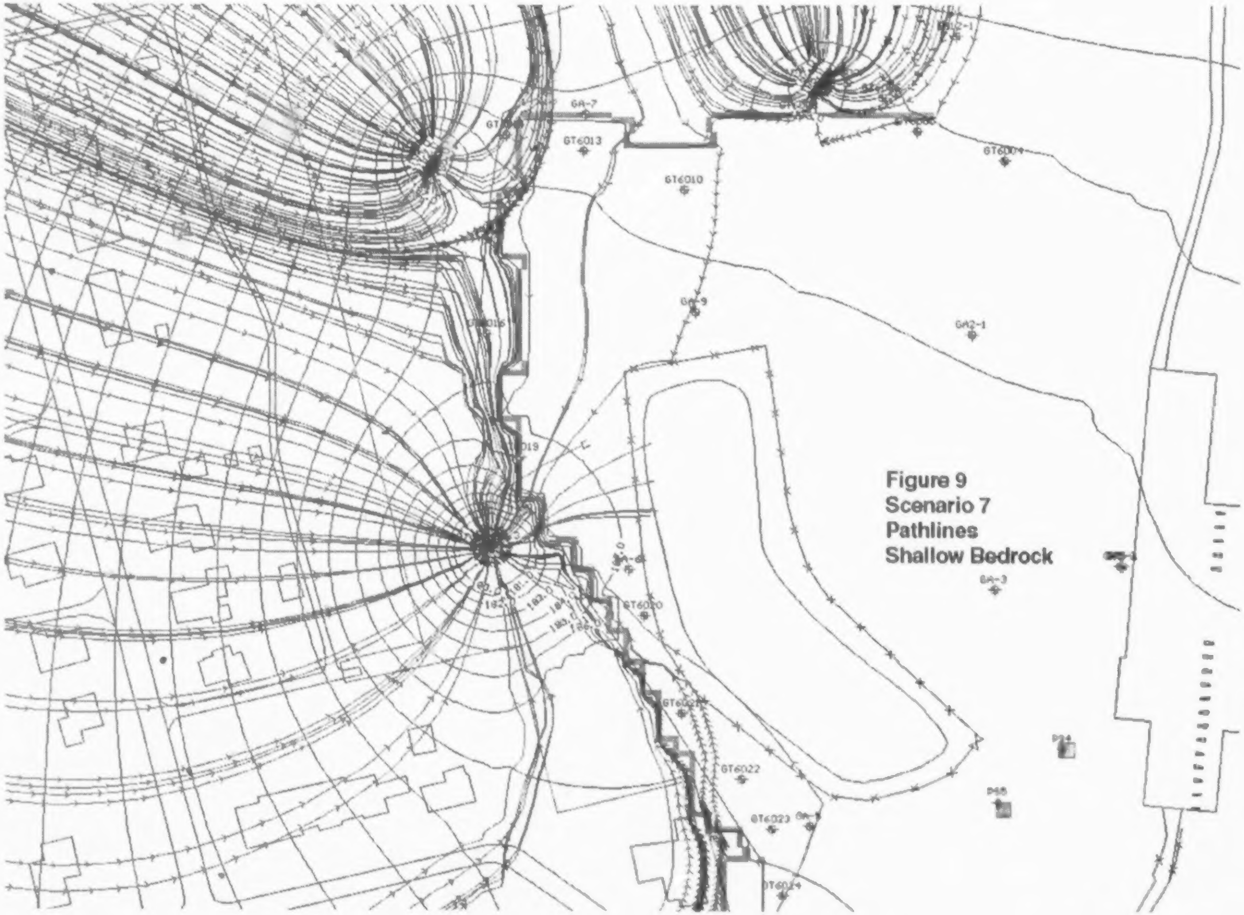


Figure 9
Scenario 7
Pathlines
Shallow Bedrock

GA-7
GT6013
GT6010
GT6004
GA2-1
GA-9
GA-3
GT6020
GT6022
GT6023
GT6024
182.0
184.0
186.0

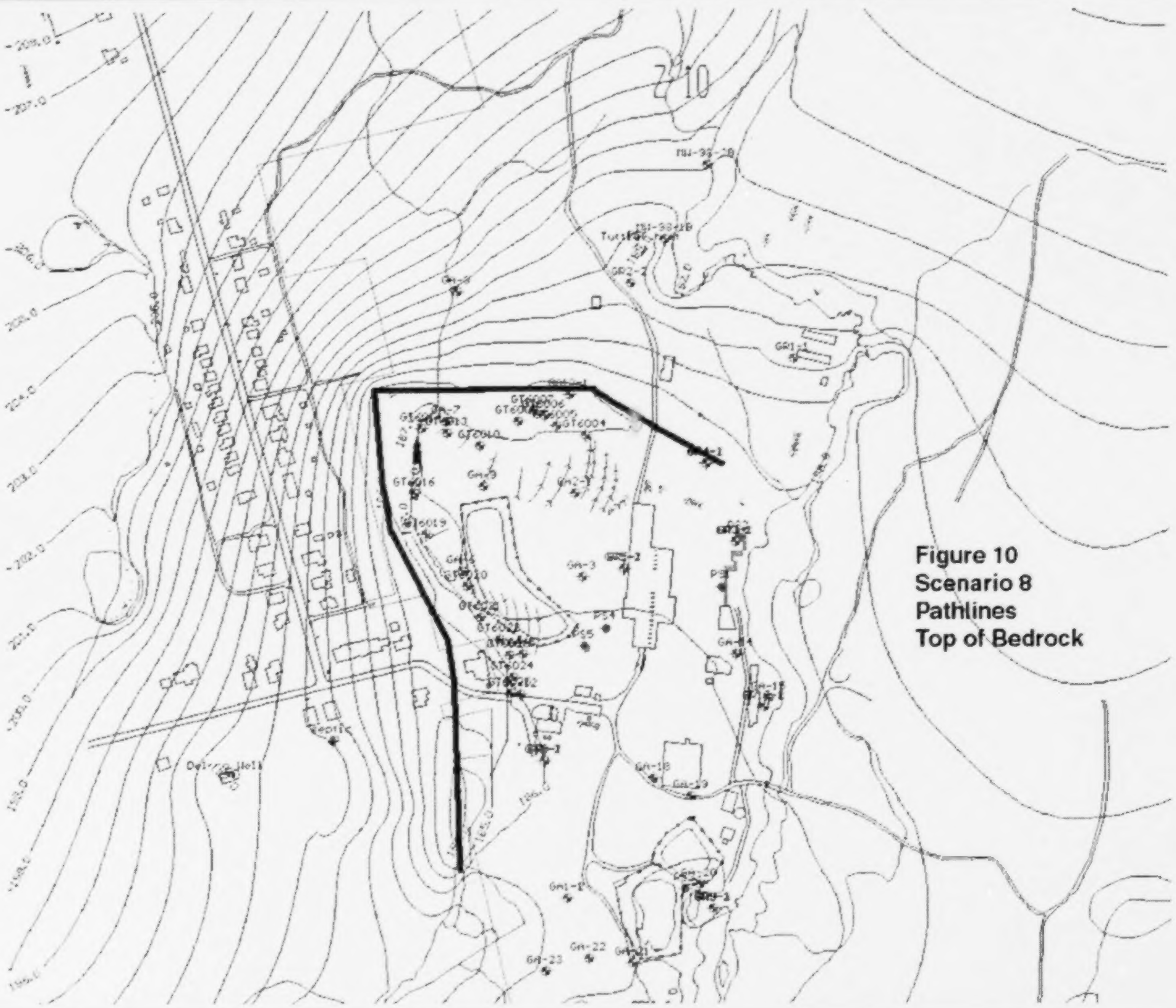

-208.0
-207.0
206.0
205.0
204.0
203.0
202.0
201.0
200.0
199.0
198.0
196.0
MW-98-1B
MW-98-1B
GR2-2
GR1-1
GM-7
GT6007
GT6006
GT6004
GT6010
GT6013
GT6016
GT6019
GM-9
GM-3
GT6020
GT6028
GT6024
GM-18
GM-19
GM-22
GM-23
GM-20
PS4
PS5
PS1
GM-4
Septic
Delmo Hall

Figure 10
Scenario 8
Pathlines
Top of Bedrock

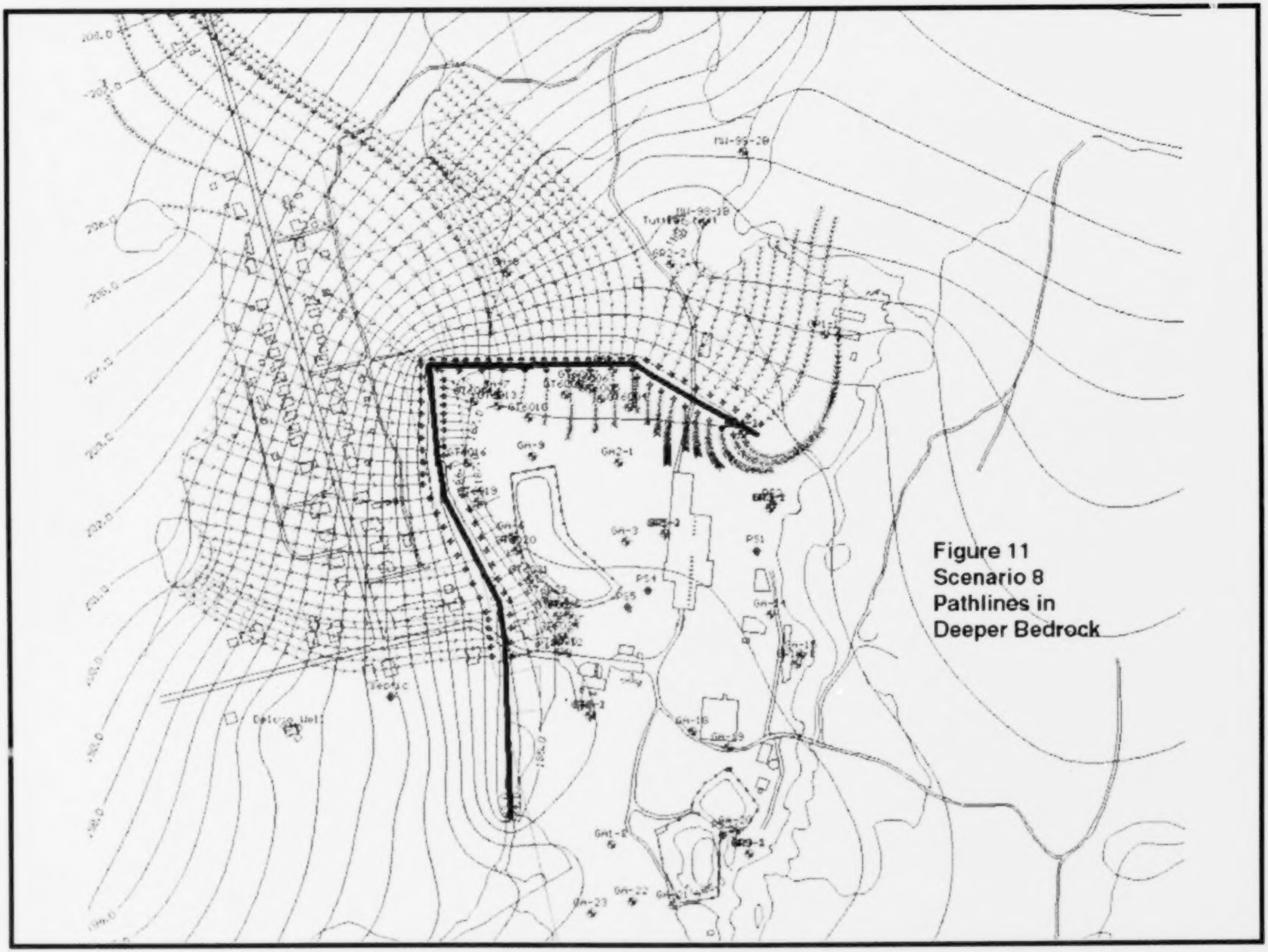
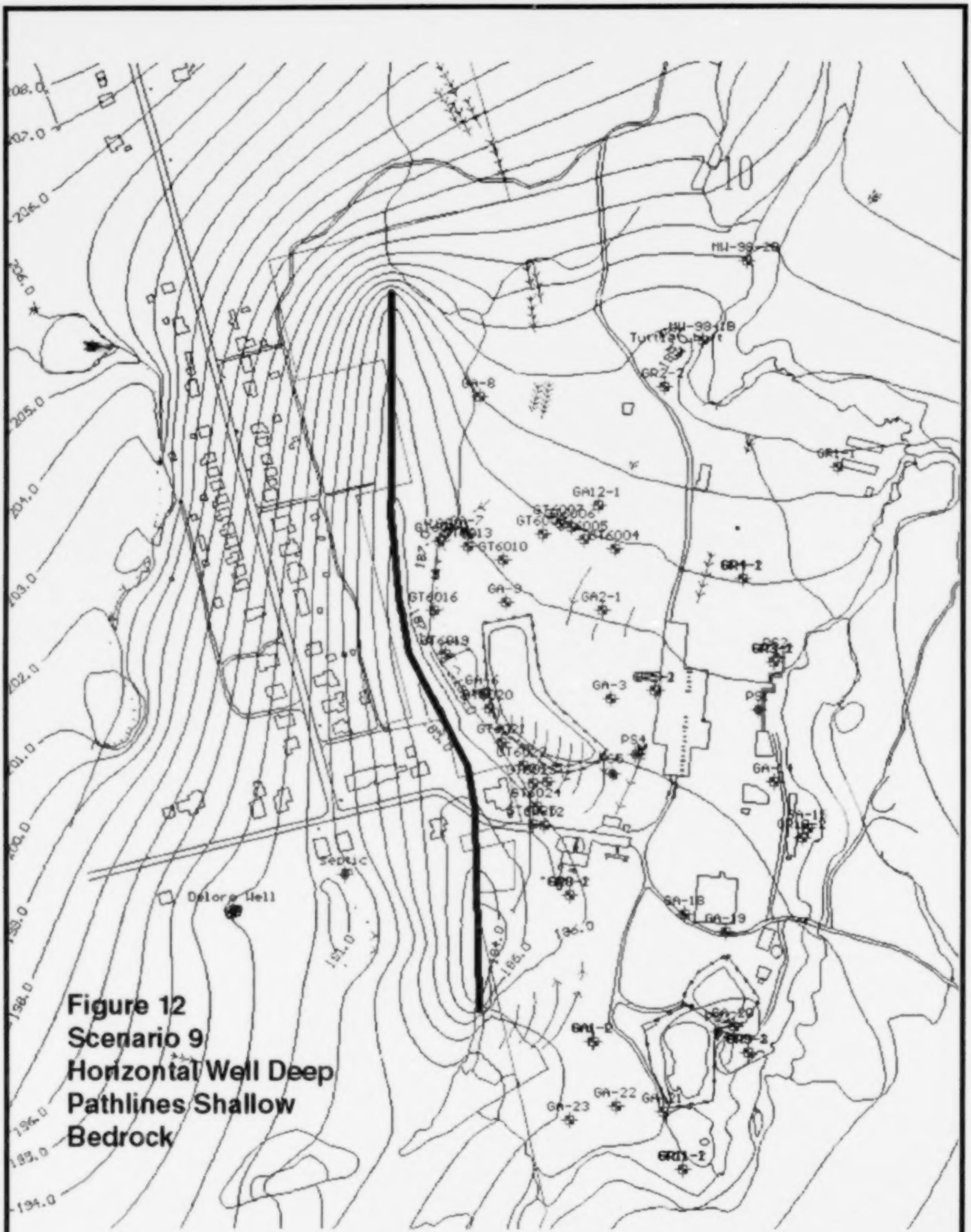

208.0
203.0
202.0
PS1
PS4
PS5

Figure 11
Scenario 8
Pathlines in
Deeper Bedrock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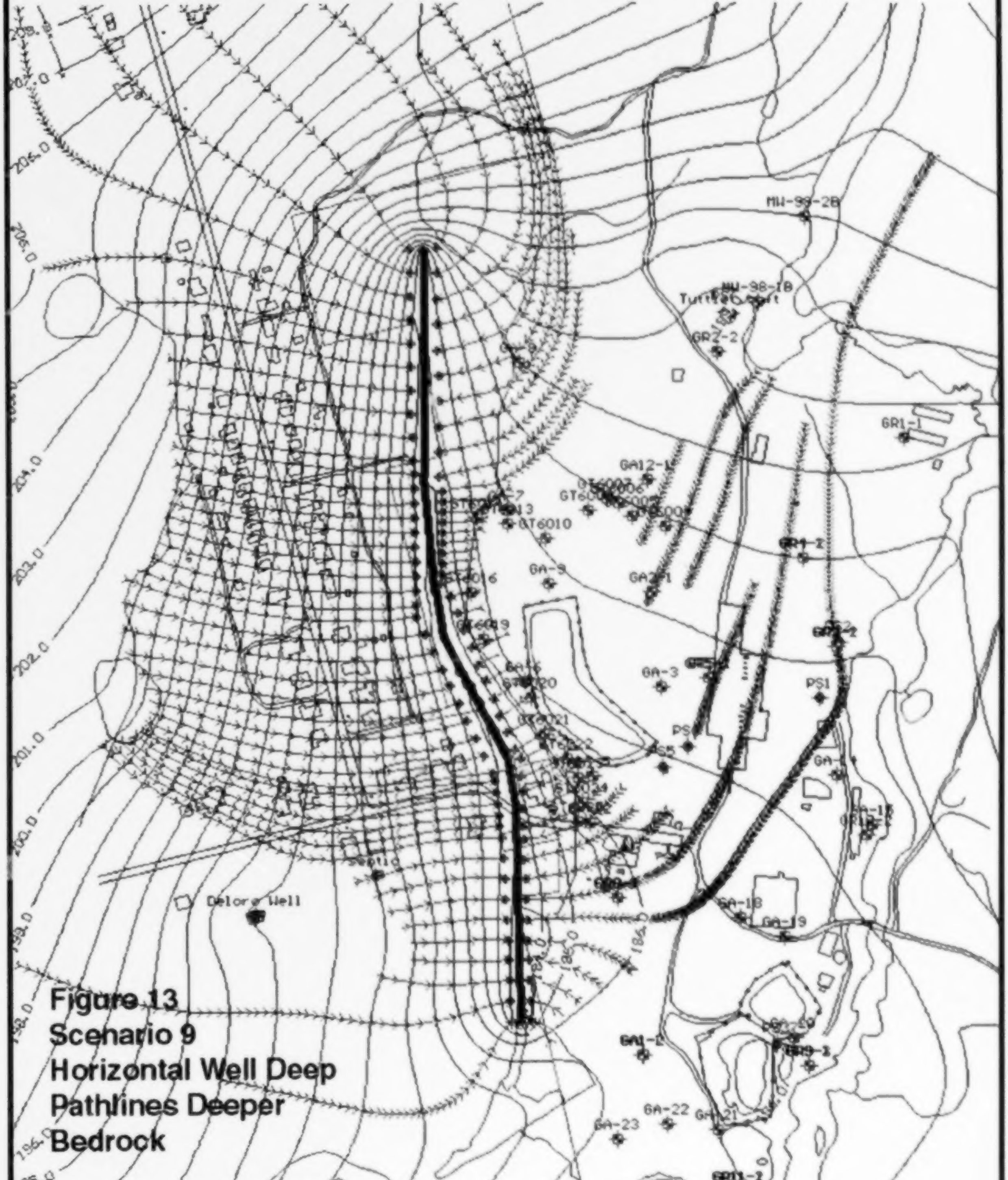
195.0
194.0
210
MW-98-2B
MW-98-1B
GR2-2
GA-8
GR1-1
GA12-1
GT6007
GT6006
GT6005
GT6004
GT6013
GT6010
GR4-2
GT6016
GA-9
GA2-1
GT6019
PS2
GR3-2
GA-6
GT6020
GA-3
PS3
GT6021
PS4
GA-14
Septic
Delore Well
GR8-2
GA-18
GA-19
191.0
184.0
186.0
GA-20
GA1-2
GR9-2
GA-22
GA-23
GA-21
GR11-2

Figure 12
Scenario 9
Horizontal Well Deep
Pathlines Shallow
Bedrock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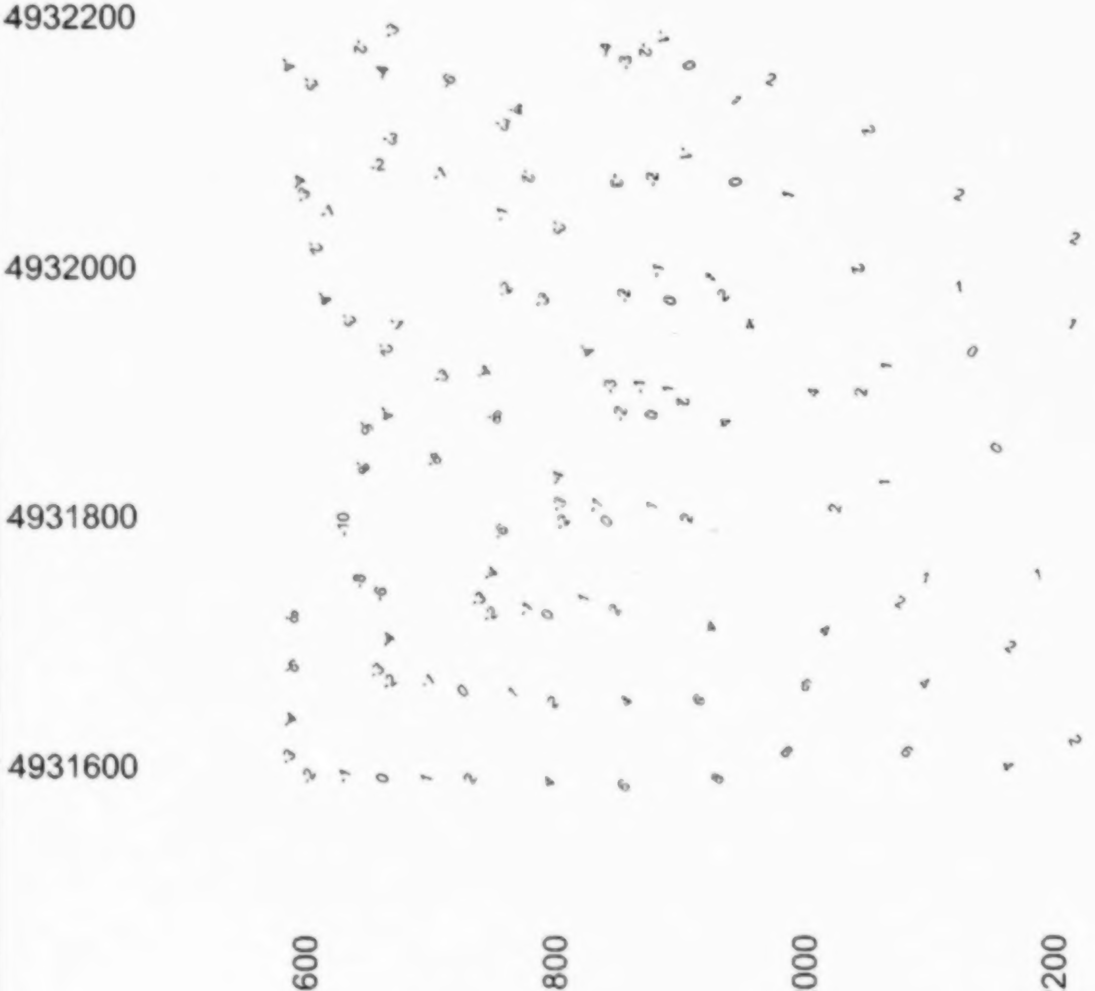
201.0
200.0
199.0
198.0
196.0
195.0
186.0
184.0
MW-98-2B
MW-98-1B
Tuttle Adit
GR2-2
GR1-1
GA12-1
GT6010
GT6016
GT6019
GR1-2
GA-9
GA2-1
GA-3
PS1
PS
GA-18
GA-19
GA-20
GA1-2
GA-22
GA-23
GA-21
GR1-2
Septic
Delore Well

Figure 13
Scenario 9
Horizontal Well Deep
Pathlines Deeper
Bedrock

Figure 14
Scenario 9
Horizontal Well No Wall
Saturated Thickness
Deeper Overburden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4931600
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292000
292200
-10
0
2

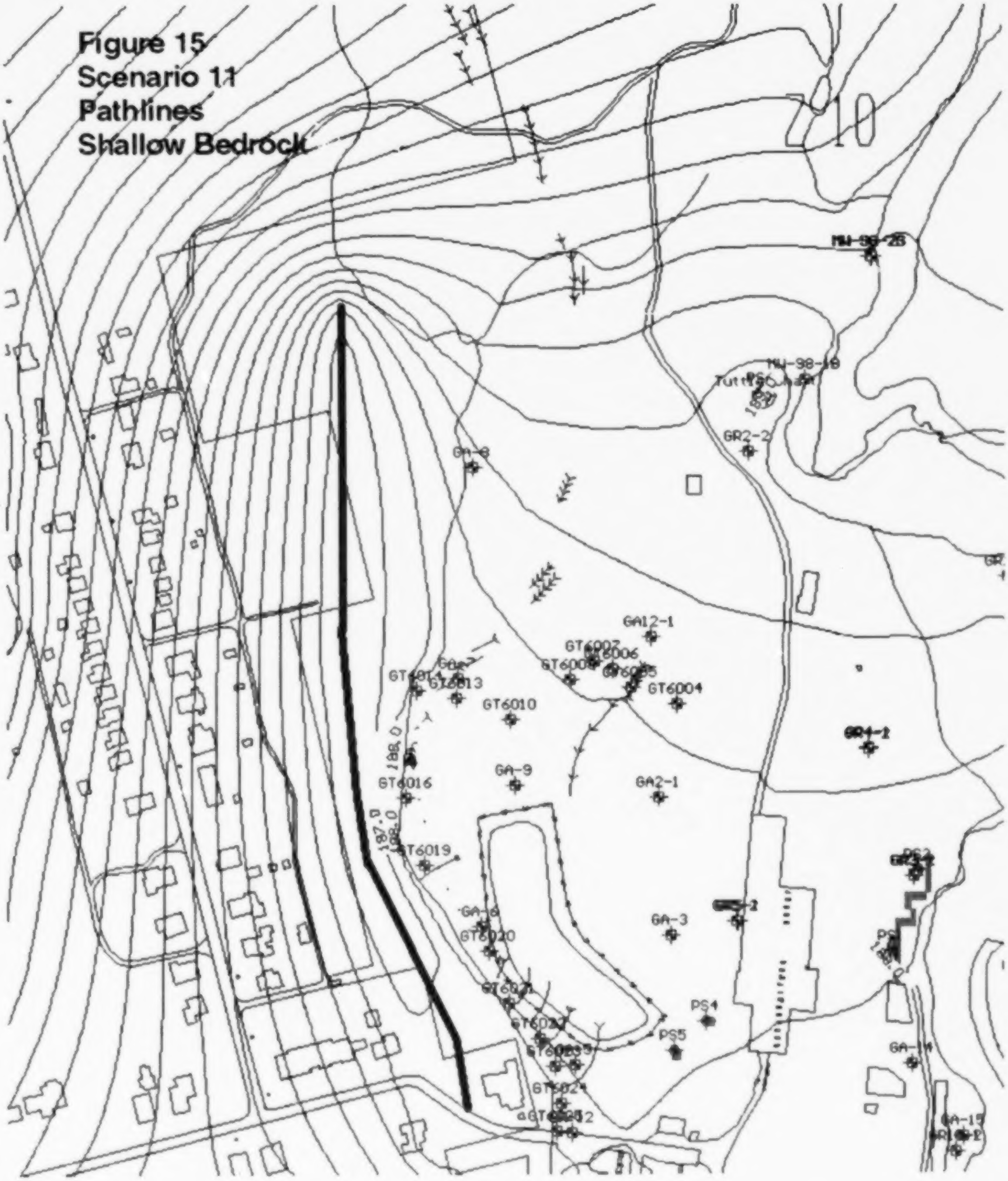


Figure 15
Scenario 11
Pathlines
Shallow Bedrock

210
GR2-2
GA-8
GA12-1
GT6007
GT6006
GT6008
GT6004
GT6013
GT6010
GR4-2
188.0
187.0
GT6016
GA-9
GA2-1
GT6019
GT6020
GA-3
GT6021
PS4
PS5
GA-14
GA-15

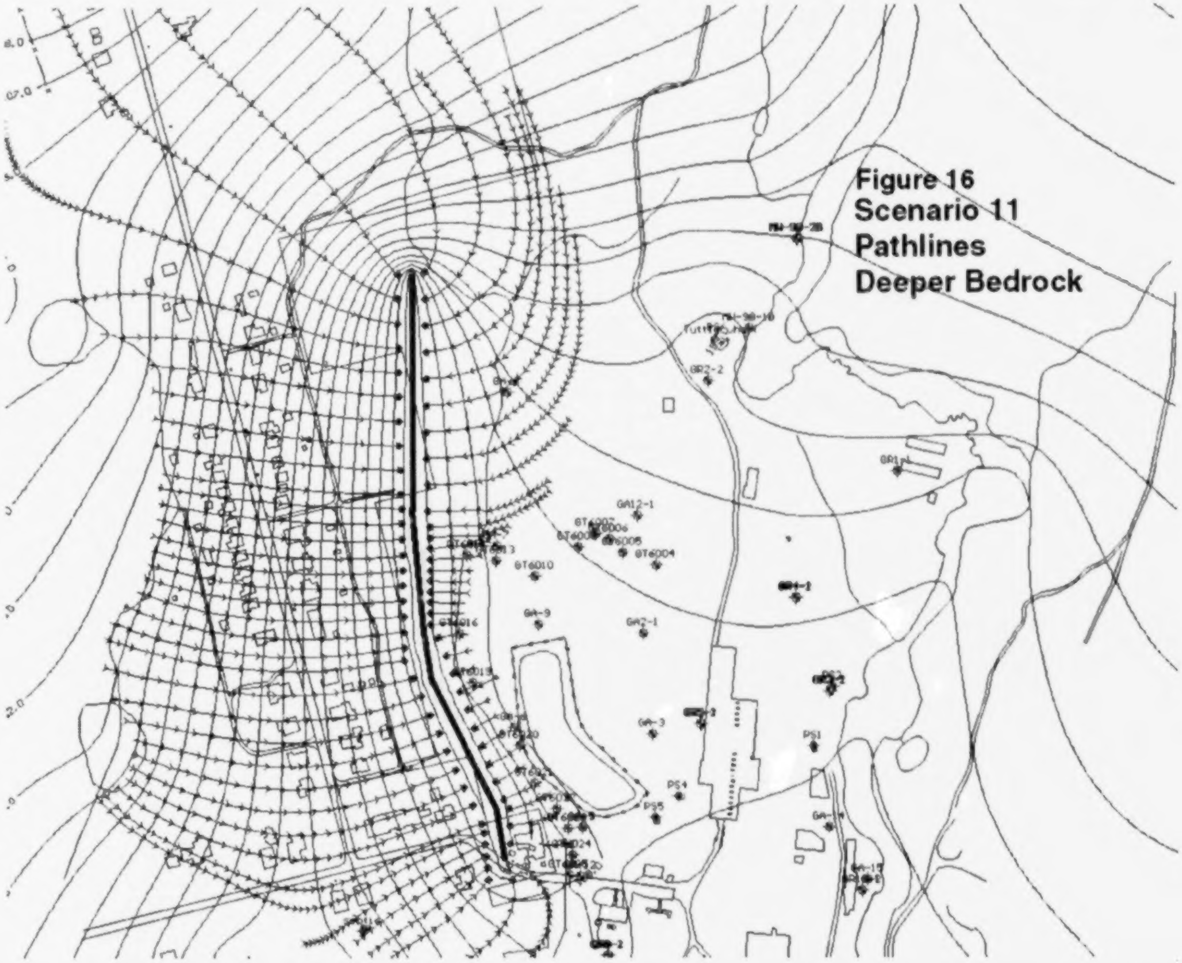
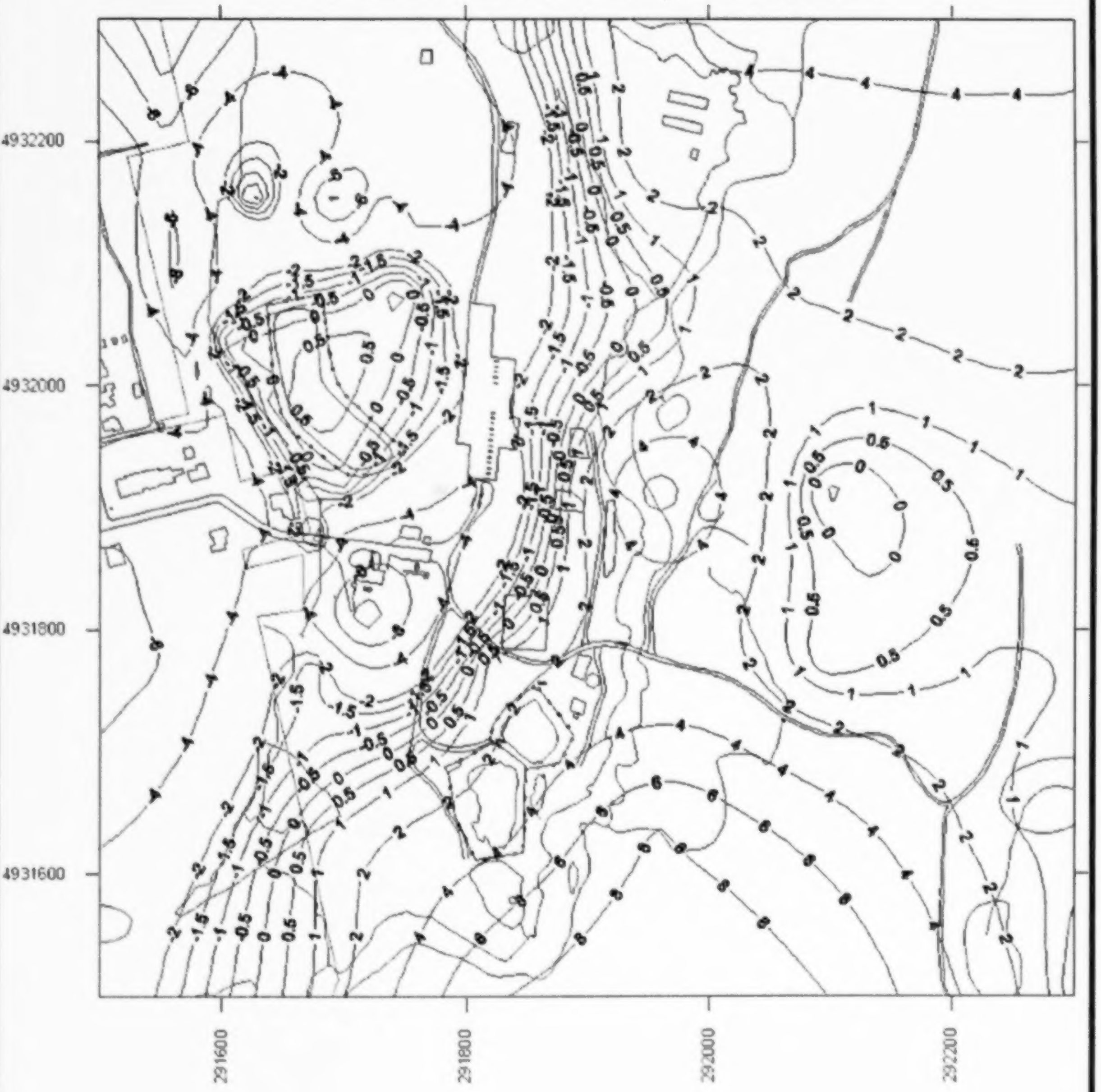


Figure 16
Scenario 11
Pathlines
Deeper Bedrock

8.0
7.0
2.0
MW-98-2B
MW-98-1D
GR2-2
GR1-1
GA12-1
GT6D05
GT6D04
GT6D10
GT6D16
GT6D18
GA-9
GA2-1
GA-3
PS1
PS4
PS5
GA-14
GA-15

Figure 17
Scenario 11
Horizontal Well to South End of Engineered Cover
HDPE Pipe to River at Property LIne
Saturated Thickness Deeper Overburden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4931800
4931600
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291800
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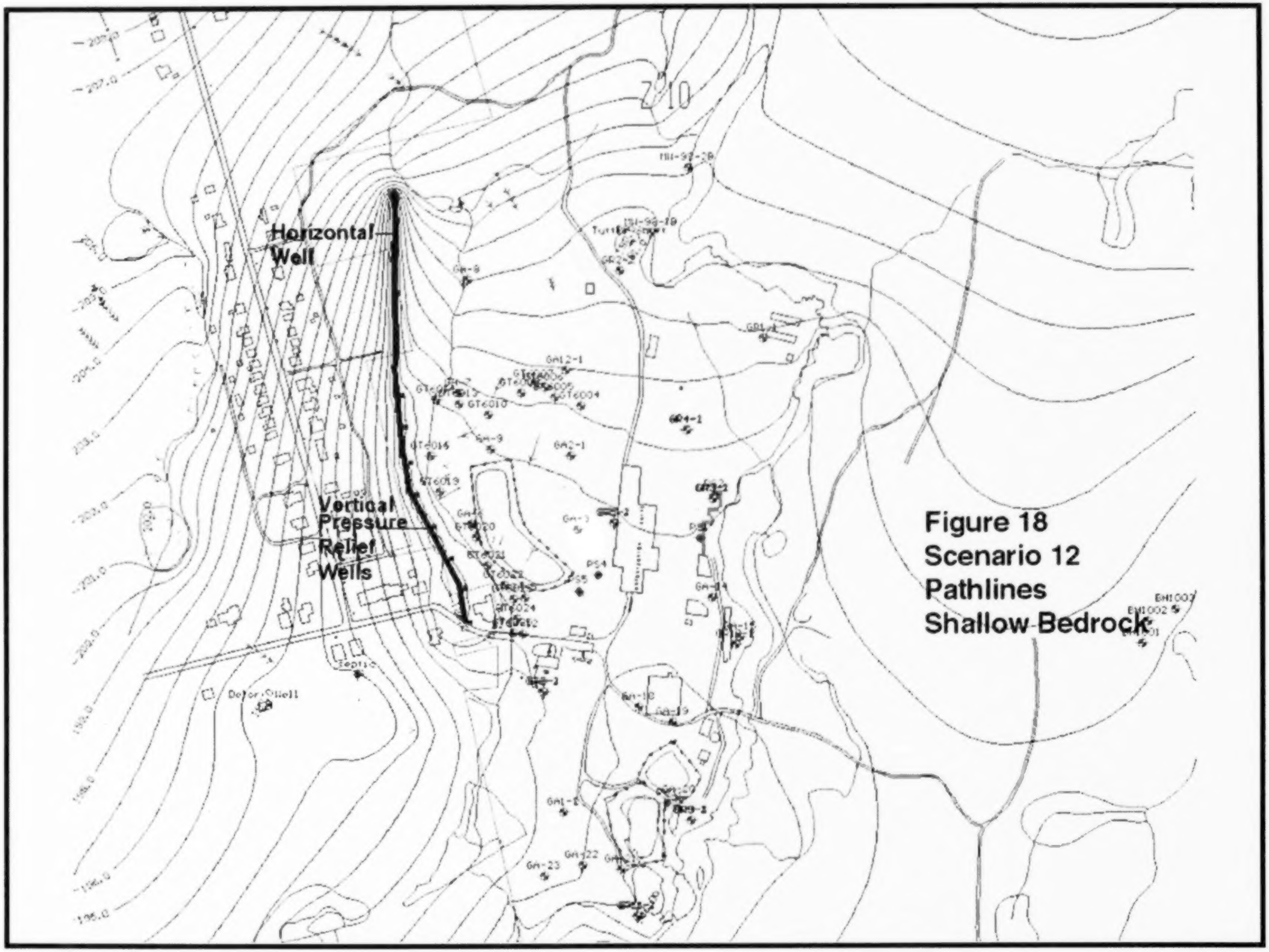
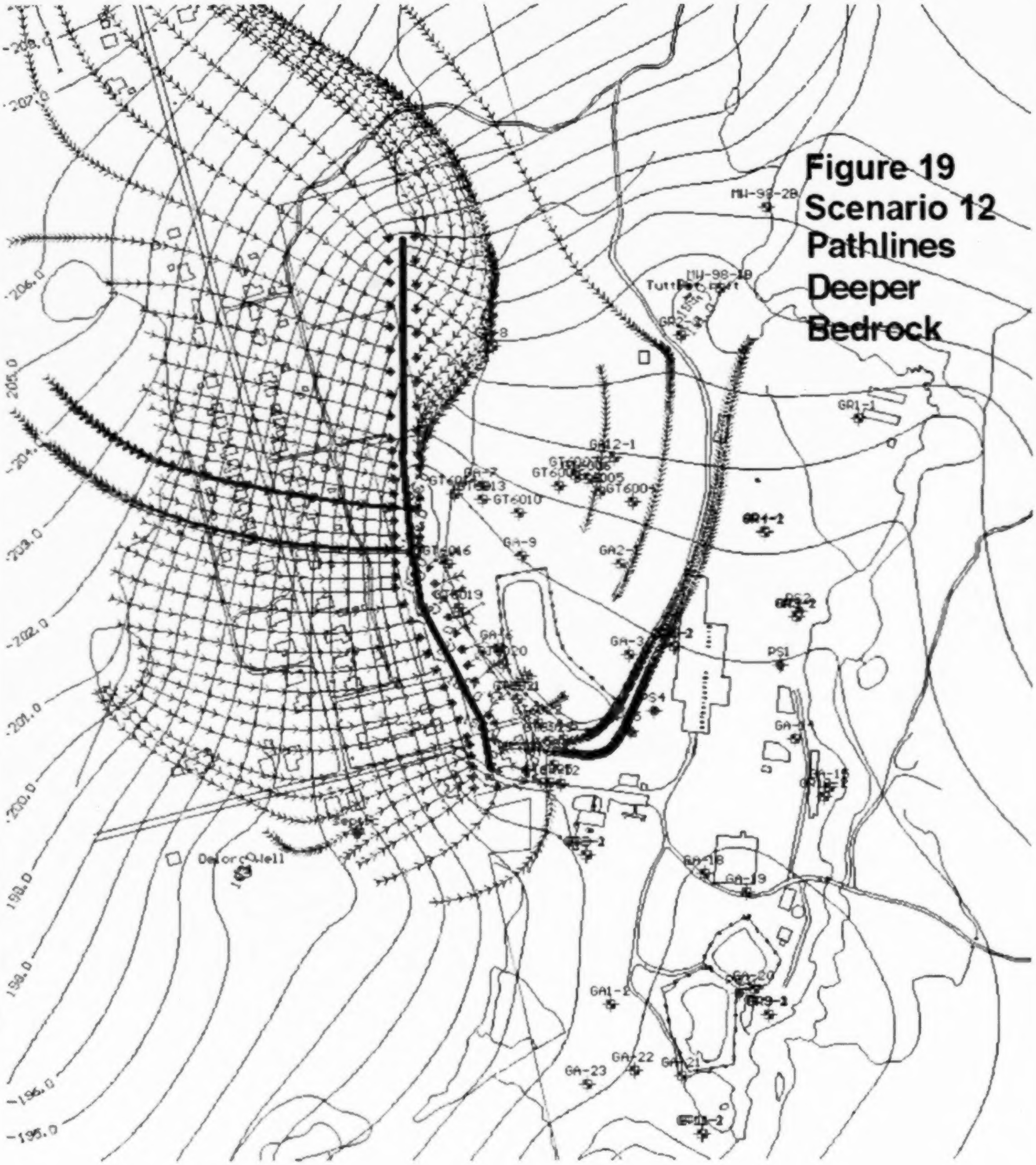
292200



Horizontal Well
Vertical Pressure Relief Wells
MH-92-2B
MH-92-1B
GR2-2
GA-8
GR1-1
GA12-1
GT6004
GT6010
GA4-1
GT6014
GA-9
GA2-1
GT6019
GT6020
GT6021
GT6024
GA-3
PS4
PS5
GA-18
GA-19
GA1-2
GA-23
GA-22
BH1002
BH1003
Septic
210

Figure 18
Scenario 12
Pathlines
Shallow-Bedrock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206.0
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199.0
198.0
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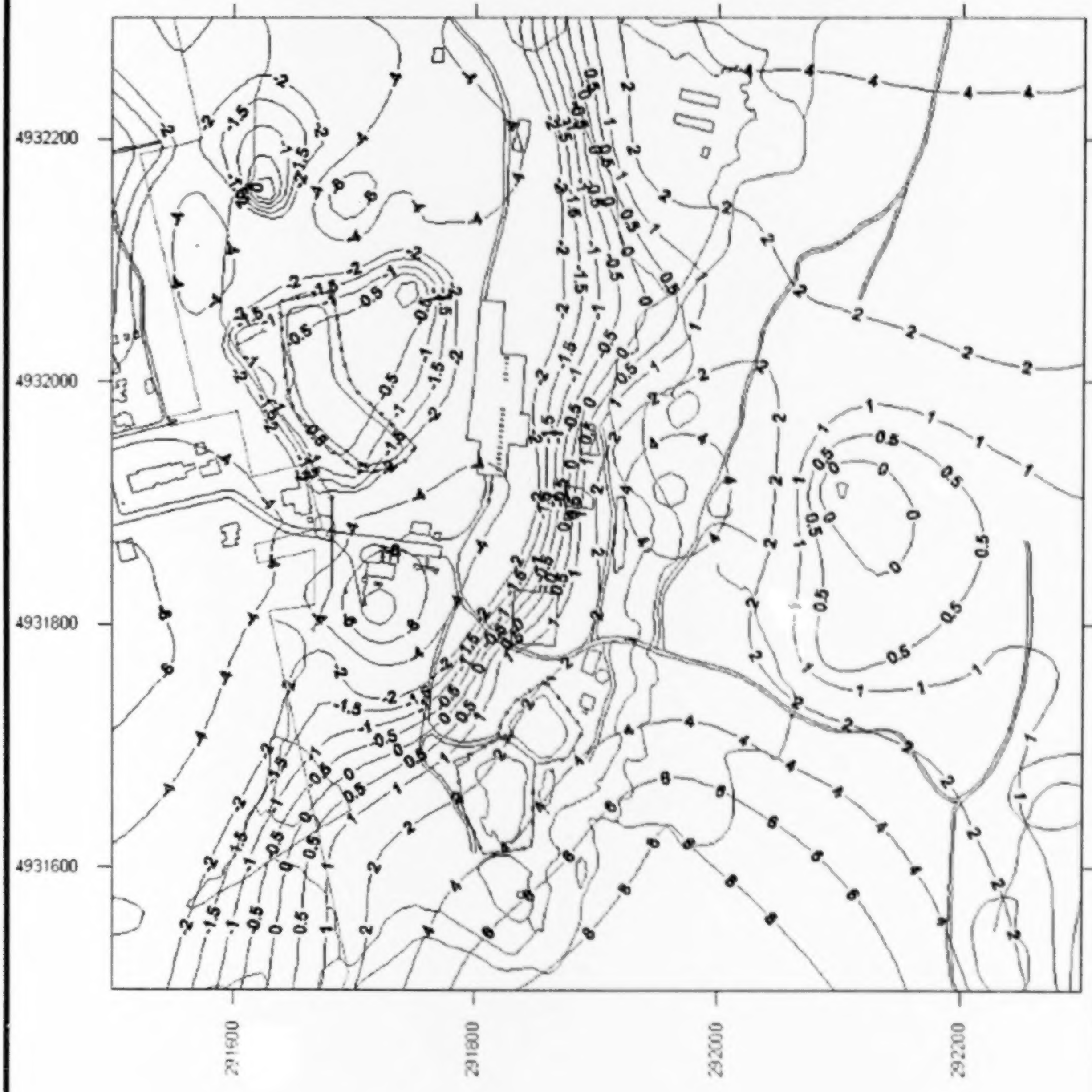
-195.0
MW-98-2B
MW-98-1B
GR1-1
GA12-1
GA-7
GT6010
GA-9
GA2-1
GT6016
GT6019
GA-3
PS2
PS1
PS4
GA-14
GA-15
GA-18
GA-19
GA-20
GA1-2
GA-22
GA-23
GA-21
DelorcoWell

Figure 19
Scenario 12
Pathlines
Deeper
Bedrock

Figure 20
Scenario 12
Horizontal Well to South End of Engineered Cover
HDPE Pipe to River at Property Line
Saturated Thickness Deeper Overburden


4932200
4932000
4931800
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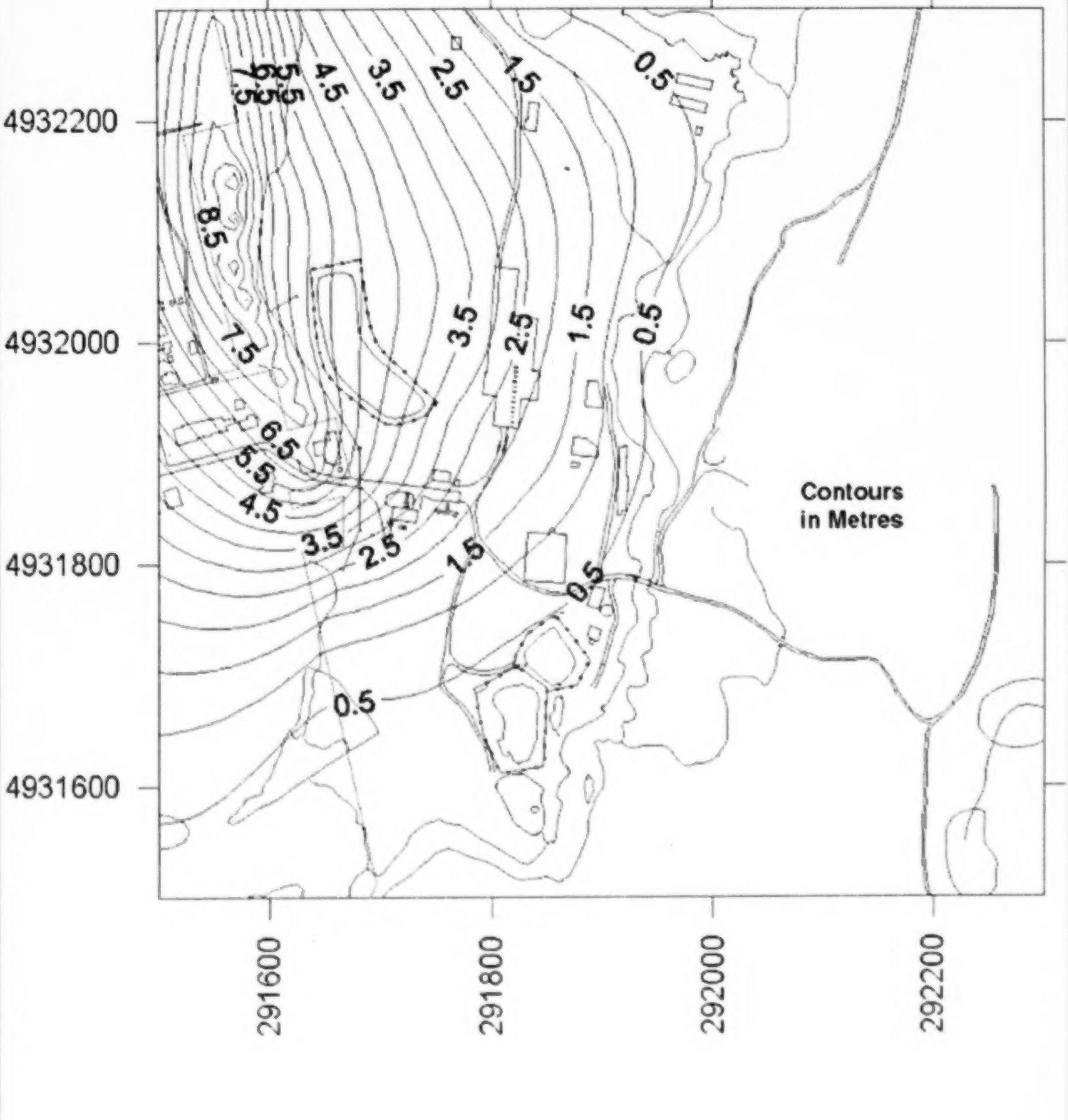
291800
292000
292200

Figure 21
Difference Between Piezometric Surface Deeper Overburden
Existing Conditions and Piezometric Surface Scenario 12


4932200
4932000
4931800
4931600
291600
291800
292000
292200
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
Contours
in Metres

APPENDIX B

SUMMARY OF MAJOR COST ITEMS FOR INDUSTRIAL AREA CLOSURE PLAN

APPENDIX B

Summary of Major Cost Items for Industrial Area Closure Plan

Opinions of Probable Construction Cost

In providing opinions of probable cost, MOE understands that CH2M HILL has no control over the cost or availability of labour, equipment or materials, or over market conditions or the potential Contractor's method of pricing. CH2M HILL makes no warranty, express or implied, that the bids or the negotiated cost of the Work will not vary from the opinion of probable construction cost.

CH2M HILL has made efforts to acquire area specific rates for materials, labour, and equipment whenever possible. The suitability of said materials to the intended purposes were not verified and will need to be determined prior to any construction activities. Where a local source or supplier could not be identified, industry budgetary tools such as the R.S. Means Company Inc. costing guide were used to assign a typical value. Appropriate regional coefficients were applied where necessary to adjust the typical costs to address regional conditions.

Each specific area of interest has been examined as an independent project. Any possible synergies associated with co-execution of various areas were ignored. Prices provided include the federal Goods and Services Tax (GST), with the exception of the operation and maintenance of the Arsenic Treatment Plant, since OCWA is GST exempt.

Volumes and areas were determined using existing available information. No additional investigations were performed to confirm or refute the estimates. Some estimates such as potential water volumes were based on engineering experience from other similar projects. Probable construction costs were based on typical weather conditions and may require adjustments due to extreme conditions.

Certain construction costs such as overhead, insurance, and various construction bonds will vary based on the potential Contractor. Financial strength, experience, and previous history all play a role in determining the rates that will be applied to a particular Contractor. These sums were determined as a percentage of the total costs based on industry averages.

Several of the site remediation options involved additional pumping to the arsenic treatment plant located in the Industrial Area. The application of a varied number of options over the four main areas will result in increases and decreases of the total treated water volume. At this conceptual stage it is difficult to determine whether there will be a net increase or decrease to the volume of water to be treated. Therefore, the operation and maintenance of the arsenic treatment plant has only been considered in the Industrial Area Closure Plan. Actual operation and maintenance costs over the last decade were used to develop a weighted-average and one standard deviation was added to this value in an effort to create a conservative estimate. Wastewater treatment considerations for all other areas were limited to collection and transmission to the equalization pond (i.e. equalization/ storage basin).

Finally, a 15 percent contingency was added to the final capital cost (before taxes, overhead, insurance, and bonds) and a 5 percent contingency was added to the final OMM costs (before taxes).

The net present value costs presented in the following cost breakdown are the sum of the capital cost and the net present value of the OMM costs. The annual OMM costs have been transformed to a net present value assuming an effective interest rate of 5 percent and a planning horizon of 20 years. The effective interest rate includes inflationary effects. It should be noted that OMM effort and costs will be required beyond the 20-year horizon. The 20-year period was selected based on the assumption that it is a reasonable period for budgetary planning purposes.

Cost opinions were developed based on information available at the time this report was prepared and are expected to have an accuracy on the order of +/- 25 percent. Use of this information for project budgeting purposes should include a factor for escalation if the contract will not proceed in the same calendar year.

Appendix B

Breakdown of Capital Costs for Work Packages and Operations, Maintenance, and Monitoring Costs

Work Package ID and Description	Cost	Insurance	Overhead	Performance Bond	Labour and Material Bond	Remote Area Cost	Final Costs*
IA-WP#1: SITE PREPARATION							
1.1 Year 1 Site Preparation	$ 211,417.24	$ 3,424.96	$ 8,245.27	$ 3,171.26	$ 3,171.26	$ 2,114.17	$ 231,544.16
1.2 Year 2 Site Preparation	$ 57,992.38	$ 939.48	$ 2,261.70	$ 869.89	$ 869.89	$ 579.92	$ 63,513.25
1.3 Year 3 Site Preparation	$ 362,623.76	$ 5,874.50	$ 14,142.33	$ 5,439.36	$ 5,439.36	$ 3,626.24	$ 397,145.54
1.4 Year 4 Site Preparation	$ 115,078.53	$ 1,864.27	$ 4,488.06	$ 1,726.18	$ 1,726.18	$ 1,150.79	$ 126,034.01
Total	**$ 747,111.91**	**$ 12,103.21**	**$ 29,137.36**	**$ 11,206.68**	**$ 11,206.68**	**$ 7,471.12**	**$ 818,236.96**
IA-WP#2: DEMOLITION							
2.1 Demolition of Buildings and Tanks	$ 216,004.04	$ 3,499.27	$ 8,424.16	$ 3,240.06	$ 3,240.06	$ 2,160.04	$ 236,567.62
2.2 Resizing and Consolidation of Ruins	$ 118,347.88	$ 1,917.24	$ 4,615.57	$ 1,775.22	$ 1,775.22	$ 1,183.48	$ 129,614.60
2.3 Haulage of Demolition Wastes to Lagoons	$ 706.46	$ 11.44	$ 27.55	$ 10.60	$ 10.60	$ 7.06	$ 773.71
2.4 Excavate, Haul, and Transport (to Landfill)	$ 104,567.09	$ 1,693.99	$ 4,078.12	$ 1,568.51	$ 1,568.51	$ 1,045.67	$ 114,521.87
Total	**$ 439,625.46**	**$ 7,121.93**	**$ 17,145.39**	**$ 6,594.38**	**$ 6,594.38**	**$ 4,396.25**	**$ 481,477.80**
IA-WP#3: RIVERBANK RECONSTRUCTION							
Temporary River Diversion	$ 43,419.49	$ 703.40	$ 1,693.36	$ 651.29	$ 651.29	$ 434.19	$ 47,553.03
3.1 South Leg	$ 317,219.66	$ 5,138.96	$ 12,371.57	$ 4,758.29	$ 4,758.29	$ 3,172.20	$ 347,418.97
3.2 North Leg	$ 167,244.87	$ 2,709.37	$ 6,522.55	$ 2,508.67	$ 2,508.67	$ 1,672.45	$ 183,166.58
3.3 North Central Leg	$ 222,993.16	$ 3,612.49	$ 8,696.73	$ 3,344.90	$ 3,344.90	$ 2,229.93	$ 244,222.11
Vegetate	$ 7,898.98	$ 127.96	$ 308.06	$ 118.48	$ 118.48	$ 78.99	$ 8,650.97
Total	**$ 758,776.17**	**$ 12,292.17**	**$ 29,592.27**	**$ 11,381.64**	**$ 11,381.64**	**$ 7,587.76**	**$ 831,011.66**
IA-WP#4: CONSOLIDATION OF WASTES							
4.1 Consolidate North IA Wastes	$ 421,708.43	$ 6,831.68	$ 16,446.63	$ 6,325.63	$ 6,325.63	$ 4,217.08	$ 461,855.08
Water Management during 4.1	$ 42,122.43	$ 682.38	$ 1,642.77	$ 631.84	$ 631.84	$ 421.22	$ 46,132.49
4.2 Consolidate South IA Wastes	$ 304,432.25	$ 4,931.80	$ 11,872.86	$ 4,566.48	$ 4,566.48	$ 3,044.32	$ 333,414.20
Water Management during 4.2	$ 65,863.17	$ 1,066.98	$ 2,568.66	$ 987.95	$ 987.95	$ 658.63	$ 72,133.34
Total	**$ 834,126.29**	**$ 13,512.85**	**$ 32,530.93**	**$ 12,511.89**	**$ 12,511.89**	**$ 8,341.25**	**$ 913,535.11**
IA-WP#5: SIMPLE EARTH (CLAY) CAP							
5.1 Simple Earth (Clay) Cap for North Industrial Area	$ 1,894,266.29	$ 30,687.11	$ 73,876.39	$ 28,413.99	$ 28,413.99	$ 18,942.66	$ 2,074,600.44
5.2 Simple Earth (clay) Cap for South Industrial Area	$ 1,767,637.06	$ 28,635.72	$ 68,937.85	$ 26,514.56	$ 26,514.56	$ 17,676.37	$ 1,935,916.11
PPE	$ 13,685.00	$ 221.70	$ 533.72	$ 205.28	$ 205.28	$ 136.85	$ 14,987.81
Total	**$ 3,675,588.35**	**$ 59,544.53**	**$ 143,347.95**	**$ 55,133.83**	**$ 55,133.83**	**$ 36,755.88**	**$ 4,025,504.36**
IA-WP#6: ENGINEERED COVER							
6.1 Clay Berm Around Perimeter of Equalization Pond	$ 73,899.00	$ 1,197.16	$ 2,882.06	$ 1,108.49	$ 1,108.49	$ 738.99	$ 80,934.18
6.2 500 mm Cover over Riverbank Wastes	$ 87,412.94	$ 1,416.09	$ 3,409.10	$ 1,311.19	$ 1,311.19	$ 874.13	$ 95,734.65
6.3 500 mm Clay Layer over Consolidated Wastes from North IA	$ 692,520.87	$ 11,218.84	$ 27,008.31	$ 10,387.81	$ 10,387.81	$ 6,925.21	$ 758,448.86
6.4 500 mm Clay Layer over Consolidated Wastes from South IA	$ 290,524.00	$ 4,706.49	$ 11,330.44	$ 4,357.86	$ 4,357.86	$ 2,905.24	$ 318,181.88
6.5 Place Remaining Layers of Engineered Cover	$ 2,000,692.92	$ 32,411.23	$ 78,027.02	$ 30,010.39	$ 30,010.39	$ 20,006.93	$ 2,191,158.88
PPE	$ 13,685.00	$ 221.70	$ 533.72	$ 205.28	$ 205.28	$ 136.85	$ 14,987.81
Total	**$ 3,158,734.72**	**$ 51,171.50**	**$ 123,190.65**	**$ 47,381.02**	**$ 47,381.02**	**$ 31,587.35**	**$ 3,459,446.27**

Appendix B

Breakdown of Capital Costs for Work Packages and Operations, Maintenance, and Monitoring Costs

Work Package ID and Description	Cost	Insurance	Overhead	Performance Bond	Labour and Material Bond	Remote Area Cost	Final Costs*
IA-WP#7: GROUNDWATER INTERCEPTOR WELL NETWORK							
7.1 Phase I: Vertical Shafts (4)	$ 1,162,379.52	$ 18,830.55	$ 45,332.80	$ 17,435.69	$ 17,435.69	$ 11,623.80	$ 1,273,038.05
7.2 Horizontal Well	$ 871,194.00	$ 14,113.34	$ 33,976.57	$ 13,067.91	$ 13,067.91	$ 8,711.94	$ 954,131.67
7.3 Phase 2 Groundwater Interceptor Well Network**	$ 484,924.53	$ 7,855.78	$ 18,912.06	$ 7,273.87	$ 7,273.87	$ 4,849.25	$ 531,089.34
7.4 Outfall Structure at End of Culvert	$ 24,610.00	$ 398.68	$ 959.79	$ 369.15	$ 369.15	$ 246.10	$ 26,952.87
Total	**$ 2,543,108.05**	**$ 41,198.35**	**$ 99,181.21**	**$ 38,146.62**	**$ 38,146.62**	**$ 25,431.08**	**$ 2,785,211.93**
IA-WP#8: SITE REVEGETATION							
8.1 Simple Earth (Clay) Cap North IA Revegetation	$ 35,992.92	$ 583.09	$ 1,403.72	$ 539.89	$ 539.89	$ 359.93	$ 39,419.44
8.2 Simple Earth (Clay) Cap South IA Revegetation	$ 29,879.99	$ 484.06	$ 1,165.32	$ 448.20	$ 448.20	$ 298.80	$ 32,724.57
8.3 Engineered Cover Revegetation	$ 165,678.38	$ 2,683.99	$ 6,461.46	$ 2,485.18	$ 2,485.18	$ 1,656.78	$ 181,450.97
Total	**$ 231,551.29**	**$ 3,751.13**	**$ 9,030.50**	**$ 3,473.27**	**$ 3,473.27**	**$ 2,315.61**	**$ 253,594.98**
Total Capital Cost							**$ 13,568,019.07**
IA-OMM#1: OPERATION, MAINTENANCE, AND MONITORING **(Net Present Value for 20 years and effective interest rate of 5 percent)**							
1. Arsenic Treatment Plant Operations (excluding GST)	$ 6,852,682.84	NA	$ 267,254.63	NA	NA	$ 68,526.83	$ 7,188,464.30
2. Sludge Disposal	$ 2,102,322.51	NA	$ 81,990.58	NA	NA	$ 21,023.23	$ 2,205,336.31
3. Site Maintenance and Monitoring	$ 1,737,682.30	NA	$ 67,769.61	NA	NA	$ 17,376.82	$ 1,822,828.73
4. Groundwater Interceptor Well Network	$ 314,140.67	NA	$ 12,251.49	NA	NA	$ 3,141.41	$ 329,533.56
5. Contingency (5% for items 1 to 4)	$ 550,341.42	NA	$ 21,463.32	NA	NA	$ 5,503.41	$ 577,308.15
Total Operation, Maintenance, and Monitoring Costs	**$ 11,557,169.73** **($927,377)*** **	**NA**	**$ 450,729.62**	**NA**	**NA**	**$ 115,571.70**	**$ 12,123,471.05**
Grand Total	**$ 23,945,791.96**	**$ 200,695.68**	**$ 933,885.89**	**$ 185,829.33**	**$ 185,829.33**	**$ 239,457.92**	**$ 25,691,490.11**

All capital costs include GST and a 15% contingency (before taxes, overhead, insurance, and bonds).

All OMM costs include GST (with the exception of arsenic treatment plant operations since OCWA is GST exempt) and a 5% contingency (before taxes).

* All costs have been developed using 2004 pricing and do not include an escalation factor.

** Pressure relief wells (8), connect 4 pressure relief wells to horizontal well, valves and flowmeters in 4 vertical shafts, hydrofracturing at 4 pressure relief well locations (before horizontal well installed).

*** Annual (Weighted) OMM costs (before overhead and remote area costs).